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COMPUTER PROGRAM FOR THIN WIRE ANTENNAS MOUNTED ON A SATELLITE BODY MODELED BY FLAT PLATES

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# **ElectroScience Laboratory**

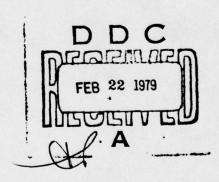
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Satellite Antennas Moment Method Diffraction

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer program is presented which employs the moment method representation of wire antennas in combination with the Uniform Theory of Diffraction to model antennas on a satellite body.

The development of the program is not completely done in that multiple diffractions are not yet included. In some analysis situations this will be of no concern while in others it may be a limitation on the use of the program.

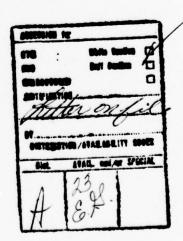
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#### I. INTRODUCTION

This report describes a computer program which analyzes impedance and pattern characteristics of wire type antennas mounted on a satellite. The satellite body is modeled by an enclosing structure of flat plates, some of which act as ground planes for the wire antennas. The basic principles and techniques for the present analysis are similar to those developed previously for the case of wire antennas on a flat plate $^{1}$ . This work extends the analysis of reference 1 to account for a more complex multiplate structure and deals with the general case where several antennas can share the same ground plane or they can be located on different faces of the satellite structure. As a result, to obtain accurate values for the antenna impedances, it is essential that all coupling terms due to reflected and diffracted fields from nearby panels and wedges as well as those due to the presence of other wire antennas must be added to the appropriate terms of the open-circuit impedance matrix. Efforts have been directed to make the present program compatible in programming logic and terminology with existing thin wire antenna programs developed by Professor J. Richmond<sup>2,3</sup>.

#### II. INPUT DATA AND SUBROUTINE CWIRE

Subroutine CWIRE is used to setup the input data for the main program. The following parameters must be specified in subroutine  $\operatorname{CWIRE}$ 

AL wire radius in wavelengths

CMM wire conductivity in megamhos/m

FMC frequency in MHz

NPGP number of wire end-points on the ground planes

NRP number of real points including those on the ground planes

NSGP number of wire segments touching the ground planes

NRS number of real wire segments.

To illustrate the working of the subroutines and main program. a satellite structure consists of 10 plates as sketched in Figure 1 is used in the examples. In the first example, a quarter wave monopole is mounted at  $(0,-\lambda,0)$  on plate 1 of the structure. Subroutine CWIRE for this case is listed in Figure 2. In the second example, another quarter wave monopole is located at the center of plate 2 and perpendicular to this plate, the corresponding CWIRE is listed in Figure 3. In both cases, CWIRE first defines the wire geometry by specifying the coordinates XC, YC, ZC of the endpoints in meters. For more complex wire structures such as that of helical antennas, a subroutine which generates XC, YC, ZC similar to subroutine HELIX of Appendix 2 can be called for this purpose. Do loop 702 generates the segment numbers and the list of end-points IA. IB for each real wire segment (Figure 2). The array element IDPT (I) specifies the plate (number) that acts as the ground plane for endpoint I. It then reads in and stores input data describing the model of the satellite structure, which include the position vectors CR of the corners and the list of corner index NPLC. Figure 1 shows the carrier index written next to the corner, numbered from 1 to 12. The plate number is written on each plate and encircled. Plate 10 is the bottom plate defined by corners 9, 10, 11 and 12. This input data for satellite geometry is labeled file IN1 in user name 3468N. Type - COPY IN1,3468N TO .IN, user name will make this file available for input to subroutine CWIRE. The data file IN1 is listed below.

```
1 .:
                          1.5
                  0.
1 1.
          -1.
                  E .
                                           ( .
                          -1.
2 -1.
          1.5
                                           -1.
                  -1.
                          2.5
                 4 -2.5
5 -2.5
5 -2.5
       2 3 H
1 4 E
7 11 E
7 1
6 5
9 8
```

The meaning of the above figures is self-explained in the following tables.

Table 1

Corner index	<u>x</u>	У	<u>z</u>
I		(in wavelengths)	
	CR(I,1)	CR(I,2)	CR(I,3)
1	1.5	-2.0	0.0
2	1.5	1.5	0.0
3	-1.0	1.5	0.0
4	-1.0	-2.0	0.0
5	2.5	-3.0	-1.0
6	2.5	3.0	-1.0
7	-2.5	3.0	-1.0
8	-2.5	-3.0	-1.0
9	2.5	-3.0	-2.5
10	2.5	3.0	-2.5
11	-2.5	3.0	-2.5
12	-2.5	-3.0	-2.5

Each plate is defined by 4 corners C1, C2, C3, C4.

Table 2

Plate Number		Corner Index		
J	C1.	C2	C3	C4
	NPLC(J,1)	NPLC(J,2)	NPLC(J,3)	NPLC(J,4)
1	1	2	3	4
2	5	6	2	i
3	2	6	7	3
4	4	3	7	8
5	5	1	4	8
6	9	5	8	12
7	9	10	6	5
8	6	10	11	7
9	8	7	11	12
10	9	12	îi	10

The position vectors CR of the corners are converted to metric units in Do 18. Subroutine CWIRE then generates the list of unit vectors VNP, where VNP (I,3) denotes the unit vector normal to plate I. The normal unit vector is defined as a cross-product of two edge vectors and points outward, away from the structure. This is done in loop Do 12. Note that the corner index NPLC (I,J), J=1,2,3,4 has been arranged such that an observer proceeds from one corner to the next on the same plate in the direction of increasing J will see the normal vector to his left, pointing outward.

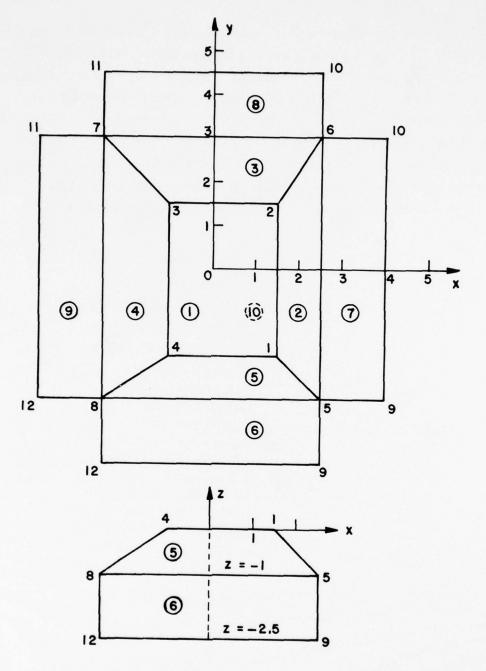


Figure 1. Model of 10-plate structure used in examples. Dimensions in wavelengths.

```
1
         SUBROUTINE CWIPE(IA.IB.IP.J.IMP.IMS.INT.TWRCJ.TWRITE.LE.P.P.MS.
          XNPP+NRS+NP+P+NSGP+AL+CMM+UPH+FMC+SCALE+TH+VG+YC+YC+ZC+ZLD+
 ٠
 3
         SVMP . NPLC . CK . NOP . NOC . IDPT . WAVM)
 14
         01"ENSION IA(1).IH(1),YC(1),YC(1),Z((1),10PT(1),VC((3),V3(3)
         DIMENSION VUP(NOP+3) . NPLC(NOP+4) . CK(NOC+3) . VF1(3) . VF2(3)
 C
         CUMPLEX V6(1),7LP(1)
 7 0
      IN (.1) AND IE (U) ARE EMPROINTS OF SPENENT J
      YC(T).YC(1).ZC(I) ARE COORDINATES OF LOID I WITH APPLICANT UNITS
 0 1
      ARP = NUMBER OF REAL POINTS. INCLUDING THOSE OF THE EFOUND FLAFE
 9 0
10 0
      MES = NUMPER OF REAL SEGMENTS
      MPGF = MUMBER OF PUTHTS OF THE CRUIMP PLANE
11 0
12 r
      NSOF = NUMBER OF REAL SEGMENTS WITH EMPROINT ON GROUND PLANE
      WILD = NUMPER OF LUMPED LOADS
15 0
14
         DU 9 U=1.ICJ
15
    9
          IUPT(J)=1
16
         ro 10 J=1.185
17
         V6(J)=(.0.0)
14
         =L0(J)=(.0..0)
      SET UP THE NEAL GENERATORS AND PEAL LUMPED LOADS
19 r
20
         1151111
21
         1612=2
22
         VG(JGM1)=(1..0.)
25 r
         V6(U6M2)=(1..0.)
24
         1 LU=0
25
         INT=0
26
         AL=0.0001
27
         CMM=-1.
20
         EMC=1600.
23
         SCALE=1.
311
         LAYMESUD./FIC
51
         TWRITE=1
32
         I WKCJ=1
30
         1564=1
34
         PPGP=1
35
         1-KS=4
3E
         CKP=5
         MS=2*NRS
37
         TH=2*NPP-NP6P
50
39 C**SET UP REAL SEAMENTS
40
         10 702 J72=1.NRS
41
          141J721=J72
42
    712
         18(372)=372+1
43
   C**SET UP THE KEAL END-POINTS
44
         10 703 ICOD=1.NRP
45
          TUPT(IONU)=1
46
          vc(Iour)=0.
47
          YC(1000)=-1.*WAVM
    704
          ¿((1001)=0.
40
44
          7C12)=WAVM/10.
```

Figure 2. Subroutine CWIRE.

```
26(3)=WAVM/8.
50
51
          76(4)=3. *WAVM/16.
52
          70151=WAVM/4.
          WRITE (5.8) IMP . NP . INS . NS
55
          IFINSGP.LT. MPGP160 TO 500
54
55
          TE (NS.GT. INS.OR.NP.GT. JNP)GO TU 500
          FORMAT(4X, 'INP='.14.5X, 'MP=', 14.5X, 'IMS=', 14.5X, 'MS=', 14)
56
57 C** SATELLITE GEOMETRY*************
58
          · UP=1U
          NUC=12
54
60
          PEAD(5.15) ((CP(II.JJ).JJ=1.3).IT=1.MOC)
          PEAD(5.16) ((NPLC([I.JJ).JJ=1.4).[[=1.NGP)
61
62
    15
          FUFMAT (AL 10.2)
63
    16
          FUPMAT (1614)
64
          nu 17 11/=1 . 110C
60
          00 16 I15=1.5
66
          CK(117.118)=CR(117.118) *WAVM *SCALE
67
    18
          CULTIMUE
68
    17
          CUNTIBUE
69
          AM=AL +WAVM
          904.1=516 ST Un
70
71
          L1=NPLC(U12.1)
72
          1,2=NPLC(-12.2)
73
          1 3=NPLC (J12+3)
74
          FU 13 J15=1.3
75
          VE1(J13)=CP(L2+J13)-CR(L1+J13)
76
    1.5
          1 L2 (J13) = CR (L3, J13) - CR (L2, J13)
77
          CALL CROSSP(VE1. VE2. VN3. V3)
78
          10 14 J14=1.3
79
          LNP(J12,J14)=VN3(J14)
    14
          CONTINUE
80
    12
81
    500
          RETURN
85
          FIND
```

Figure 2. (Cont'd).

```
1
         SUBROUTING CHIRE (I, . 14. ICU. INP. INS. INT. I ARCU. IMPITE . MELIC. PP. MS.
         SUPPONES ONE SPONSOFOAL OCHOOLIPPOFME OSCALE OTHOROXCOYCOZCOZE SO
         S VMP . NPLC . CH . NOP . NOC . ILPT)
 5
         TIMENSION IN(1).IH(1).XC(1).YC(1).ZC(1).TUPT(1).VNB(5).VE(3)
         PIMENSION VEP(MOP+3)+MPLC(MOP+4)+CR(MUC+3)+VF1(3)+VE2(3)
          COMPLEX VG(1),ZLD(1)
 1.
      IA(J) AND IB(J) ARE EMPROINTS OF SECHENT J
 7 C
      XC(1) . YC(1) . ZC(1) ARE CLOROTNATES OF POINT I WITH ARRITHARY WAITS
 11 1
 9 1
      THEP = NUMBER OF REAL POINTS. INCLUDING THOSE ON THE GROUND FLARE
11 0
      TRS = NUMBER OF REAL SEGMENTS
11
      "HOL - MUMBER OF POINTS OF THE GROUND PLANE
12 C
      MSGP = NUMBER OF REAL SEGMENTS WITH ENCROLLET ON GROUND PLANE
      FILL = NUMBER OF LUMPER LOADS
15 C
14
         00 9 J=1.ICJ
    9
15
          ILPT(U)=1
16
         PO 10 J=1.1MS
17
         V6(J)=(.11.0)
18
         7LD(J)=(.0..0)
      SET UP THE REAL GEMERATORS AND PEAL LUMPER LOADS
19
         J641=1
20
21
         J61 2=2
22
         16 (JGH1)=(1..0.)
23
         16(06112)=(1.000)
24
         MLN=0
25
          INT=0
26
         AL = U. Ufin1
27
         CMM =- 1 .
20
         FMC=1009.
24
         SCALE=1.
30
         WAVM=SUD. /F "C
31
          TWPITE=1
32
         IWRCJ=1
33
         "SGP=2
34
         PGP=2
35
         MK5=0
36
         ** KP=10
57
         NS=2*MFS
30
         MP=2*NRP-MP-6P
39 C**SET UP REAL SEGMENTS
40
         ru 702 J7c=1.NRS
41
          14(J72)=J72
42
    702
          18(372)=372+2
43 PARSET UP THE HEAL EMD-POINTS
         ru 705 I=1.5
44
4:7
          1000=2+1-1
40
          10PT (1001)=1
47
          YC(IOUT)=0.
41
          YC(1000)=-1.*WAVM
44
    765
         70(1000)=0.
```

Figure 3. Subroutine CWIRE.

```
50
          7C(3)=VAVM/16.
51
          7C(5)=VAVM/6.
         7C(7)=5.*WAVM/16.
52
53
          20(9)=WAV4/4.
         WHITE (6.5) INP. NP. INS. NS
54
          TE (NSGP.LT. PGP)60 TO 500
55
          IF (NS.GT.INS.OR.NP.GT.INP)GO TO 500
56
57
         FORMAT(4x, *) NP= * . 14.5x, *NP= * . 14.5x, *IUS= * . 14.5x, *NS= * . 14)
56 C** SATELLITE GEOMETRY************
59
         8.0P=10
60
         NOC=12
         PEAD(5.15) ((CR(II.JJ).JJ=1.3).IT=1.NOC)
61
         READ(3.16) ((NPLC(II.JJ).JJ=1.4).II=1.80P)
62
    15
63
         FURMATIALIDAE)
64
    16
         FUPMAT(1614)
65
         00 17 117=1 . NOC
66
         no 18 T18=1.3
         CK(117.118)=CR(117.118)*WAVM*SCALE
67
68
    19
         CONTINUE
69
    17
         CONTINUE
70
         AM=AL*WAVM
71
         90% 12 J12=1 . MOP
72
         L1=NPLC(3)2.1)
13
         12=NPLC(J12.2)
74
         1 3=NPLC (U12.3)
75
         nu 13 J10=1.5
76
         VE1(J13)=CF(L2.J13)-CR(L1.J13)
77
    13
         WE2(J18)=CR(L3.J15)-CR(L2.J13)
78
         TALL CROSSF (VE1. VE2. VN3. Va)
79
         00 14 014=1.3
80
    14
         WNP(J12,J14)=VN3(J14)
81
    15
          COMTINUE
82
          00 704 I=1.5
33
          JEVEN=2+1
84
          JUPT (IF VEN) =2
          XC(IEVEN)=(2.+VNP(2.1)*(1-1)/16.)*WAVE
85
86
          YC(IFVEN)=VMP(2+2)*(I-1)*WAVM/16.
87
    704
          7C(IEVEN)=(-0.5+VNP(2.3)+(I-1)/16.)*HAVA
80
    500
         PETURN
89
          FINE
```

Figure 3. (Cont'd).

#### III. THE MAIN COMPUTER PROGRAM

The main computer program is listed in Figure 4. This program calls subroutine CWIRE for input data, namely the geometry of the wire antennas and the multiplate structure. The program next calls subroutine CSORT to generate appropriate image points and image segments. CSORT also sets up the dipole current modes for the wires and their images. Each dipole mode I has segments JA(I) and JB(I), terminals at point  $I_2(I)$ , and endpoints  $I_1(I)$ ,  $I_3(I)$ . Subroutine CSORT generates the following information:

ND(J)	number of dipole modes sharing segment J							
MD(J,K)	list of dipoles sharing segment J							
NCM	size of the compressed open-circuit impedance matrix							
N	number of dipole modes of the complete systems							
IDSEG(J)	the plate (number) that acts as the ground plane							
	for segment J.							

The following quantities must be specified in the main program.

ICC	dimension the compressed matric $C(I,J)$
ICJ	dimension related to the number of dipole modes ${\bf N}$
INP	dimension related to the number of points NP
INS	dimension related to the number of segments
NOP	number of plates of the structure
NOC	number of corners of the structure.

The numerical values assigned to the above quantities must agree with the dimensions actually reserved for the corresponding quantities in the COMPLEX and DIMENSION statements. For example when the structure has only one plate NOP=1, correspondingly we must redimension all related vectors, e.g.,

DIMENSION NPLC(1,4), VNP(1,4)

instead of

DIMENSION NPLC(10,4), VNP(10,4) for the 10-plate case.

X(I), Y(I), Z(I) denotes the dimensionless quantities kx, ky, kz for point I where  $k = 2\pi/\lambda$ . XC(I), YC(I), ZC(I) denotes the coordinates x, y, z in meters.

The main program calls subroutine CMATX (Appendix 10) to generate the compressed open circuit impedance matrix C(I,J). CMATX performs the same function as subroutine IDANT of Reference 3. The main difference lies with the addition of coupling terms due to reflected and diffracted fields in the matrix.

The program next calls subroutine ANTI (reference 3) to obtain the resultant current distribution on the wires and the radiation efficiency EFF. If the wire antennas have only one generator and VG = (1.,0.) then  $Y_{11}$ ,  $Z_{11}$  denotes the antenna input admittance and impedance respectively (see example 1, section IV). If there are more than one generator; input impedance at input port J can be obtained by dividing VG(J) by CJ(J) (see example 2, section IV). (Note that if the generator excites a point on the ground plane - CJ(J) should be used, as the current for the ground plane dipole mode is defined in reverse direction from those of the real modes (see also reference 3)).

Finally the antenna pattern is obtained by calling subroutine CIFFLD (appendix 11). TH and PH denote the spherical coordinates  $\theta, \phi$  in degrees of the distant observer. CIFFLD is called once for each observed direction, TH, PH. CIFFLD is essentially the same as subroutine IFFLD of reference 3 except for the call CZFF. Patterns in xy, yx, xy planes are obtained by setting pattern indicators IXY, IYZ, IXY respectively to a positive integer value, if all indicators assume zero or negative integer values no pattern is computed. The resultant patterns are stored in library file PLDATB ready for plotting.

```
OPTIONS 52K
          OPTIONS UP
          INCLUDE THNGPP. 3468NIVPR3. 3468N
 3
          INCLUDE MESSR. SYS9 : PACE . 3468M
          INCLUDE CSOFTB. TEMP1 100AMB. TEMP1
 0
          INCLUDE FIELDR. TEMP1
 7 0
            THIN-WIRE HELICAL ANTENNA OVER FINITE PERFECT GROUND PLANE
 9 (****
            SINUSOIDAL-GALERKIN FREGUENCY-DOMAIN
10 (****
            CALCULATE E-TH COMPONENT
11 0
12
          COMMUNICUMIC
          CUMMON/CUM1/CJ.VJ.CG
13
          COMMON/CUM2/CGD.SGD.DC
14
15
          COMMON/COM3/IA.IB.JA.JB.T1.I2.13
          COMMON/COM4/TOTAL T
16
17
          CUMMON/CUME/VG.ZLD
          COMMON/COME/X.Y.Z.YC.YC.ZC.CR.NPLC.VNP.MO.NU.D.10SEG.IDFT
18
19
          COMMON/CUM9/CDK.SUK.VNN.VN3.V3.VEI.VEZ
20
          COMPLEX (JI . ET1 . E | 2 . EP1 . EP2 . EPPS . ETTS . EPTS . ETPS . ZH . VP . VT
          COMPLEX EPH. ETH. Y11. Z11. ZH. EPP. ETT
21
          COMPLEX C(32.32).CGD(65),SGD(65),CG(130).VG(130).ZLD(130)
55
          COMPLEXIOTALI(361)
23
          COMPLEX (J(70) . VJ(70)
24
          PIMENSION IDSEG(65) . IDPT(70)
25
          DIMENSION XC(70) . YC(70) . ZC(70) . X(70) . Y(70) . Z(70)
26
27
          OIMENSION CR(12.3).0(65).00(65).VNN(3)
          DIMENSION IA(65) . IB(65) . MU(65 . 4) . ND(65) . CDK(65) . SDK(65)
20
29
          DIMENSION 11(70) +12(70) +13(70) +JA(70) +JF(70)
          PIMENSION NPLC(10.4).VMP/10.3).VH3(3).V3(3).VE1(3).VE2(3)
30
31
          NATA PI. TP. ETA/3.14159265.6.2831853.376.727/
32 C** TXZ.IYZ.IXY ARE FIELD PATTERN INDICATORS IN XZ.YZ.XY PLANES
          DATA IXZ/-1/, TYZ/-1/, IXY/-1/
33
34
          CALL SUPERRIST
35
          CALL SUPERRIA)
          CALL SUPERRIST
36
          CALL ASSIGN (6HDA01
37
                                .0. .61
          CALL ASSIGN (6HPLDATB . 0 . 0 . 4)
38
          CALL DEASSN
39 C
40
          CALL LUDEL (3)
41
          100=32
42
          TCJ=70
43
          INP=70
44
          INS=65
45
          F10=180./PI
46
          FOPMAT(8X,*UPP=**15,5X,*MAX=**15,5X,*MIN=**15,5X,*MIN=**15,5X,
     1
47
         2 . NCH= . . 12)
48
          FOPMAT(PX, *AL=*.F8.6.5X.*CHM=*.F8.4.5X.*FMC=*.F8.2)
     2
49
          FORMAT(8x, *EFF= * +F7.2.3x, *Y11= *.2F8.2.3x, *Z11= *.2F8.2)
```

Figure 4. Main program.

```
1
```

```
50
     5
         FURMAT(110)
51
         EURMAT (1x.2F10.0.4F10.2)
52
    7
         FURMAT (5X . * HERF *)
         CALL CWINE (IA. TH. ICU. INP. INS. INT. IMPCU. IMPRITE . NELLO NP. NS.
53
54
          55
          "VMP.MPLC.CR.NOP.NOC.IPPT.WAVM)
56
           57
         CALL CSORT(IA, IH+1CC+1CJ+INS+1wRITE+11+12+13+JA+JR+
50
        >MAY.MIR.MD.M.NCM.ND.NP.NS.NRP.NRS.MPGP.MSGP.NC.XC.YC.ZC.
59
         SAME MARTE OCH ONOL ONOL OIDSEPOIDAL
      NOM = SIZE OF COMPRESSEU MATRIX CIL.UI
61 C
         JED = MCM - MEPE
61
         FRITE (6.1) JPP , MAX + MIN + M + MCM
61
         PRITE (6,5)
63
64
         IF (N.LF. & . OR. N. GT. ICJ) GU TO and
         1F (NCM.61.100)60 10 500
65
66
         IF (MAX.LE.C .OR. MIN.LE.D)GO TO ENU
67
         AK=TP*AL
         HKTTE (6.2) AL . CMM. FMC
19
69
         UFTTE (6.5)
70
         THE = TP/WAVE
71
         10 90 J=1.NS
72
     90
         f(J) = IPL * BC(J)
73
         00 100 I=1. P
74
         \times (I)=TPL*XC(I)
75
         Y(T)=TPL*YC(I)
74,
     100 7(1)=TPL*20(1)
77
         CALL CMATX(ICC+4+JPP+MP+N+NCM+NC+
78
         PNLO.NP. NEGI. NRS. NS. AK. CMM. D. FMC. CDK. SUK. -1. WAVE.
79
         ZAM+XC+YC+ZC+CR+VNP+NOP+NOC+NSup+HPLC+X+Y+Z+InsEG1
89
         1.0 11 J11=1 .MS
         SGD(J11)=CMPLX(0..SDK(J11))
81
82
    11
         CGD(J11)=CMPLX(CDK(J11).n.)
83
         T12=1
84
         CALL AMTI(IA.JP.II.JZ.J3.1WRCJ.JWRITF.112.ICC.IMS.JA.JR.
         ·UPP·MD·N·N(M·NU·MLU·MFGP·NFS·NS·C·CPCK·SDK·CU·CAM·O·O·FFF·G·VG·Vd·
85
85
         * Y11 . Z11 . ZH . ZL n)
87
         IF (112.NE.12)GO TO 500
         WRITE (F. 3) EFF . Y11 . 711
80
         IF (G. t G. 1. AND. EFF. EG. n. ) GO TU 500
89
         CALL RITE (IA. IR. IMS. D. II. 12. 73. MD. NO. 08. CU.CG)
911
         TF(1x2.L1.1)60 TO 606
91
9%
         WRITE (5.7)
93
         CHAX=U.
74
         nu 602 I=1,361
         IF (I.LF.101)TH=1.*(I-1)
95
         IF (I.Lt. 151)PF=0.
90
         TF(1.6T.181)TH=1.*(361-1)
97
90
         IF (1.6T.181)PH=180.
99
         CALL CIFFLUCIES.MD.N.ND.NRS.CDK.CJ.DC.
```

Figure 4 (Cont'd).

```
REPHOETHOGO GPPOGTT . PHOSDKOTHOXCOYCOZCO WAVMOAMONPGPO
100
           SNCM . VAP . MFLC . CK . NOP . NOC . IUSEG!
101
102
           IF (GIT. GI. GMAX) GMAX=GTT
105
     602
           TUTALT(1)=ETH
104
     603
           FURMAT (4115.5)
105
           WRITE (4) (TUTALT(I) . I=1 . 361)
106
           TF (GMAX.GT.B.) DBM=18. *ALOGIN (GMAX)
107
           PRITE (6.604)08M
108
           FURMAT(5x *** MAXIMUM POWER GAIN = .. F19.2. D8./)
     604
109
           1F(1YZ.LT.1)60 TO 614
     606
           GMAX=U.
110
111
           00 608 1=1.361
112
           TF(I.LE. 181) TH=1.*(I-1)
113
           TF(I.LE.181)PH=90.
114
           JF(I.GT.181)TH=1.*(361-I)
           TF(1.6T.181)PH=270.
115
           CALL CIFFLICINS.MD.N.ND.NRS.CDK.CJ.DC.
116
           SEPHOETHOGOGPPOGTTOPHOSDKOTHOXCOYCOZCOWAVMOAMONPGPO
117
118
           SNCM. VNP. HPLC. CH. NOP. NOC. IL'SFG)
119
           IF (GTT.GT.GMAX) GMAX=GTT
120
     6118
           TOTALT(I)={ TH
121
           WRITE (4) (TOTALT(1) . I=1 . 361)
122
           IF (GMAX. GT. G.) DBM=10.*ALOGIC(GMAX)
123
           URITE (6,604) UBM
124
     614
          CLOSE 4
125
      500 CALL EXII
126
           FINIT
```

Figure 4 (Cont'd).

#### IV. EXAMPLES

### A. A Quarter Wave Monopole on Plate 1

The monopole is located at  $(0.,-\lambda,0.)$  on plate 1 of the structure in Figure 1. It is fed with 1 volt delta gap generator at the point of contact with the ground plane. The output file DA $\phi$ 1 as generated by the program is listed in Figure 5. Input impedance  $Z_{11}$  is (40.12+j21.8) ohms. If the same monopole is located at the center of a square plate 200 $\lambda$  each side, computation with the present program yields  $Z_{11}=39.66+j21.54$  ohms, which is the same value as that of a quarter wave monopole mounted on an infinite ground plane obtained with programs of reference 3. Far field patterns in x-z, and y-z planes are shown in Figures 6 and 7, without inclusion of doubly diffracted fields. These patterns agree well with those independently generated by R. Marhefka's GTD computer program  $^4$ .

```
1
        1. P= 70
                       "P=
                              9
                                      INS= 60
                                                     1.5=
                            PLATE
           10(J) IB(J)
                                       K IN(K) TH(K) PLATE HO(U)
                                                                .01875
               1
                                       5
                                             1
                                                   6
                                                          1
         1
 5
                                                                .01675
                     3
                                1
                                                   7
                                                          1
               c.
                                                                ·n1875
                                             7
               3
                     4
                                       7
         3
                                1
                                                   ò
                                                          1
 7
                                             \boldsymbol{\epsilon}
                                                   9
                                1
                                                                .01875
                                                          1
 6
               xC(1)
                           AC(1)
                                       ZC(I)
                                                         YC(J)
                                                                    YC(J)
                                                                                 20(3)
         J
                                                   J
10
              0.00006
                          -.50000
                                      0.00000
         1
                          -.50000
11
              0.00000
                                                        0.00000
                                       .01875
                                                                   -.50000
                                                                               -. 11875
         4
                          -.30000
                                                                   -.59000
10
         ċ
              0.00000
                                       .03750
                                                   7
                                                        0.00000
                                                                               -.03750
13
                          -.30000
              0.00000
                                       .05625
                                                        0.00000
                                                                   -.30000
         4
                                                   8
                                                                               -. 05625
14
              0.00000
                          -. 50000
                                       .07500
                                                   5
                                                        0.00000
                                                                   -.30000
                                                                               -.07500
15
16
              JA
                          11
                                15
                                      13
                                                                   JB
         1
                    UB
                                                              JA
                                                                         11
                                                                               12
                                                                                     13
17
               1
                     5
                           2
                                       4
         1
                                 1
16
                     2
         2
               1
                           1
                                 2
                                       *
                                                              5
                                                                           1
                                                                                 6
                                                                                      7
                                                                     6
19
                     3
                           2
                                                                     7
                                                                                 7
         3
               2
                                 5
                                       4
                                                               6
                                                                           in.
                                                                                      8
20
                           3
                                       £.
               3
                                 4
                                                                                      9
                                                               7
21
23
             JPP=
                      3
                             MAX=
                                       2
                                                                     7
                                              = 11 1
                                                       1
                                                               11=
                                                                             NCM=
                                                                                       4
23
24
            AL= .000100
                               CMM= -1.0000
                                                   FMC= 1000.00
25
26
             VG( 1) =
                                1.00
                                            0.00
27
20
                                  PHISE
               I
                    MACHITUDE
                                                   REAL
                                                                 IMAGINARY
20
                                               -. 0192407
               1
                      1.000
                                  151.5
                                                                  .0104584
30
                        .949
                                                .0178567
               1
                                  -30.7
                                                                 -.0106141
                        .748
51
               3
                                  -32.0
                                                .0138884
                                                                 -.0086997
                                  -33.1
                                                .0078523
32
               4
                        .428
                                                                 -.0051110
33
34
            FFF= 100.00
                             Y11=
                                                                          21.01
                                        .02
                                                -.01
                                                         711=
                                                                 46.14
```

Figure 5. Output file.

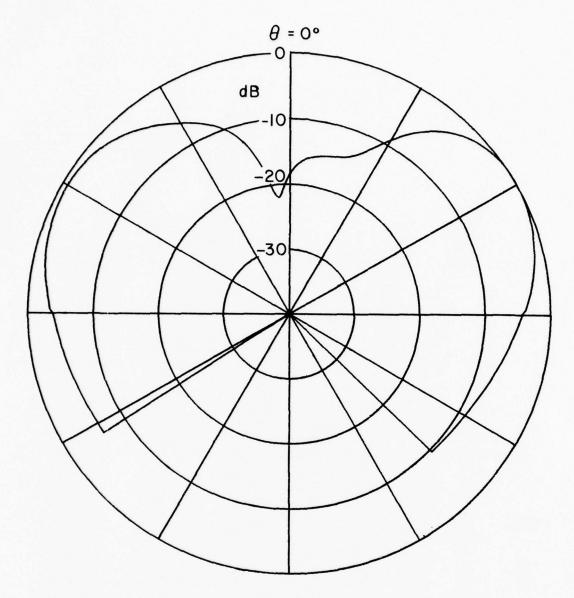


Figure 6. Pattern in the x-z plane.

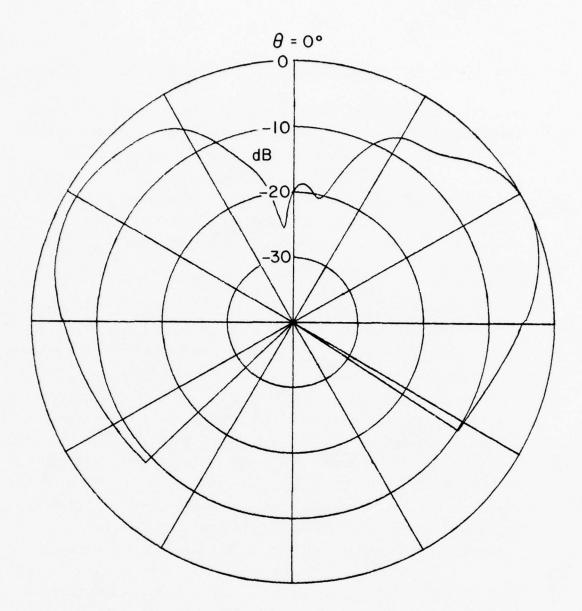


Figure 7. Pattern in the y-z plane.

### B. Two Quarter Wave Monopoles on Plate 1 and Plate 2

Consider the second example where the first monopole is located as in example 1. The second monopole is at center of face 2 or at  $(-2\lambda,0.,-0.5\lambda)$  in x, y, z coordinate system as shown in Figure 1. The 2nd monopole is perpendicular to its ground plane and fed with 1.0 volt delta gap generator at ground plane end. Output file DA $\phi$ 1 resulted from this program is listed in Figure 8, where input impedances for monopole 1 and 2 are  $Z_{11}$  and  $Z_{22}$  respectively.

More importantly, the knowledge of the coupling or interference effects between wire antennas mounted on the satellite is essential in the design stage to evaluate alternative arrangements. The present program is well equipped for this purpose. For example, let us consider the case of two quarter wave monopoles mounted on plates 1 and 2 of the satellite (Figure 9). Here we wish to study the amount of interference or coupling between the two monopoles. Monopole on plate 1 is excited with a 1 volt delta-gap generator, and the program (DOAN1 $\varphi$ , 3468N) computes the complex voltage  $\rm V_{12}$  which appears across the 50 termination of receiving monopole on plate 2. A plot of  $\rm V_{12}$  versus distance  $\rm d_2$  is shown in Figure 10, where  $\rm d_2$  denotes the separation of the receiving monopole from the edge.

The dB plot shows a change in the slope of  $|V_{12}|$  close to d<sub>2</sub> ~ 1.08 $\lambda$ , where the receiving monopole starts seeing the direct incident field from the monopole on plate 1.

1 2	Il <sub>t</sub> P=	70	^	F=	18	In S	= 65	V	S= 1	16				
3	J [	^(J)	18 (J)	PI	LATE	K	IV(K)	IB(K)	PLAT	TE IC	(J)			
4	1	1			2	a	1	11	1		01275			
5	ď	2	4		2	10	5	12	2		01875			
6	3	3	5		1	11	11	15	1		n1875			
7	4	4			2	12	12	14	2		01875			
()	5	5	7		1	1.3	1.5	15	1		01875			
9	to	6.	E		2	14	14	16	2		01875			
10	7	7	٠		1	15	15	17	1		01675			
11	8	3	10		2	16	16	16	2		01875			
12														
13	1	XC	(1)	YC	(I)	ZC	(1)	J	YC.	(J)	YL	(U)	Zc	(U)
14	1	0.0	0000	3	oneo	0.0	0000							
15	2	. 6	1000	0.0	DULE	1	Scen							
16	3	0.01	0000	3	0.000		1875	11	0.90000		50000		01875	
17	4	.6	1326	0.0	0.00	1	SF.74	12	.58674		0.00000		16326	
10	3	0.00	0000	5	0.000		3750	13	0.00000		30000		03750	
19	6	. 63	2652	0.0	0.000	1	2308	14	.57	7345	0.0	0000	17	7652
20	1	0.09	0006	5	uara	. 0	5625	15	0.00	1000	5	9000	05	625
21	8	. 6	3977	0.0	0000		1023	16	.56	5023	0.0	0000	16	3977
25	9	0.0	1000	5	uunn	.0	75 NU	17	0.0	0000	5	0.000	0	7500
23	10	. 6	3303	0.0	0000	0	9697	16	.54	1697	0.00	0000	20	303
24														
25	1	JA	uB.	11	15	13			ĸ	JA	JB	11	12	13
26	1	1	9	3	1	11								
27	2	2	10	4	2	12								
28	3	1	3	1	3	5			9	9	13	1	11	13
29	4	2	4	2	4	5			10	10	12	5	12	14
50	5	3	5	3	5	7			11	11	13	11	13	15
51	6	4	£1	4	6	8			12	12	14	10	14	16
52	7	5	7	5	7	9			13	1.3	15	15	15	17
53	6	6	(3	6	8	10			14	14	16	14	16	18
34														

Figure 8. Output file.

```
MAX= 2 MT1= 1 1= 14
                                                             NCM= 8
          JPP= 6
35
36
                        CMP = -1.0000 FMC = 1000.00
          AL= .000100
37
30
                                   0.00
                         1.00
39
          V6( 1) =
                         1.00
                                   0.00
          161 51 =
40
41
                                                    IMAGINARY
                                         REAL
               MAGNITUDE PHASE
            1
42
                                      -.019654x
                                                     .0101365
                            152.8
                   .977
45
            1
                                       - 050555
                                                      .0102030
                            153.2
                  1.000
414
            2
                                       .0182652
                                                     -. (103135
                            -20.5
45
            3
                   . 926
                                        .0187630
                                                     -.0103724
                            -28.0
                   .947
46
            4
                                        ·614566c
                                                     - . 61164571
                            - 56 . A
            L,
                   .730
47
                                                     -.0054569
                                        .0145883
                   .745
                            -30.0
48
            6
                                                     -.0049792
                                        .0080358
                   .417
                            -31.8
            7
49
                                        .0082450
                                                     -.0049996
                   .426
                            -31.2
            8
ÓÜ
51
          FFF= 100.00 Z11= 40.15 20.60 Z22= 39.42 19.89
52
```

Figure 8 (Cont'd).

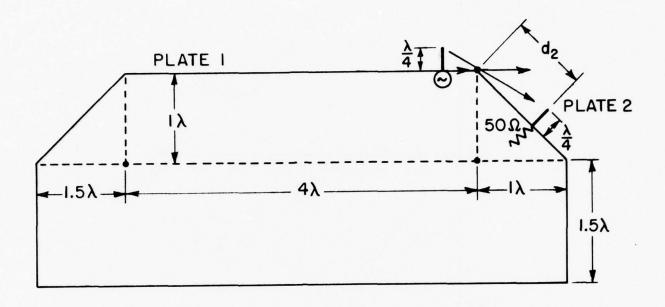


Figure 9. Satellite with a two antenna coupling problem.

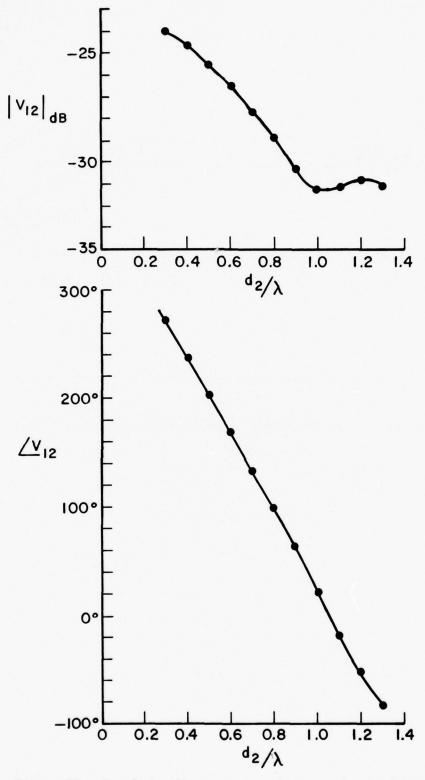


Figure 10. Coupled voltage of the configuration in Figure 9.

# APPENDIX 1 SUBROUTINE CROSSP

CALL statement

CALL CROSSP (V1, V2, VN3, V3)

This subroutine computes the vector of products of V1 and V2

$$\vec{v}_3 = \vec{v}_1 \times \vec{v}_2$$

 $\overline{VN3} = \frac{\overrightarrow{V3}}{|\overrightarrow{V3}|}$  unit vector of cross product.

The listing of CROSSP is shown in Figure A.1.

Figure A1. Subroutine CROSSP.

### APPENDIX 2 SUBROUTINE HELIX

This subroutine is listed in Figure A.2. It describes the geometry of helical antennas.

CALL statement

CALL HELIX (XC, YC, ZC, IA, IB, CIRCM, ALFA, TURN, NANT, AXIS, ASTAR, NRS, NRP)

INPUT.

CIRCM:

Circumference of helix

ALFA:

Pitch angle

TURN:

Number of turns

NANT:

Number of helical antennas

AIXS(NANT,3): Position vector of the feed point of the helical

antenna NANT

ASTAR(NANT,3): Position vector of the standing point of the helical

antenna NANT (or end point of the connecting segment)

OUTPUT

XC,YC,ZC:

Coordinates of end points of all segments of the

helical antennas

IA, IB:

List of index of end points

NRS:

Number of real segments

NRP:

Number of real points.

```
1
          CUPROUTIBE HELIX(XC.YC.ZC.IA.LE.CIRM.ALFA.TUBM.AANT.AXIS.ASTAR
 2
        1.NRS.NRP1
 5
         1 1 MEUSICH X((00).Y((50).Z((00).In(100).IH(100).A1(5)
 4
         I-IMENSION AXIS(5.5) . ASTAR (5.7)
         1 ATA PJ. 18/1.14155265.1.2651553/
         1 1=P1/4.
 0
 7
         1 U 1 1=1. 1/1 T
         FI=ASTAP(1,0)-AXIS(1,2)
 9
         C2=ASTAR(1.1)-AX1S(1.1)
11.
    1
         A1(I)=ATAN2(81.82)
11
         PKF=MANT
14
         HO=CIKH/IH
15
          1F(ALFA,UE.P1/2.0.OR.ALFA.MF.5.*P1/2.) P4=83*TAN(ALFA)
14
          TF (ALFA. EU. PI/2.0. OR. ALFA. EG. 3. *PI/2.) 84=83
15
         M=TFIX(TURN *6.)+1
16
          00 2 1=1.M
17
         00 3 J=1. PAPIT
18
          T=AT(U)+(I-1)*DI
19
         MKP=MKP+J
20
          xC(NRP)=/XIS(J.1)+F3*COS(T)
21
         YC(MRP)=AXIS(J.2)+83*SIM(T)
22
         7C(NRP)=ASTAR(J.3)+84*(T-AT(J))
23
         CULTIMIT
    3
24
    2
         CONTINUE
25
         00 4 1=1. PAT
26
         xC(1) = AXIS(1.1)
27
         YC(1)=/X1S(1.2)
38
         7C(I)=AX1S(I.3)
20
         PRS=NKP-MAPIT
31
         00 5 I=1 . WES
31
         TA(1)=I
32
    5
         18(1)=1+0pr T
33
         PLTURN
         FINI
54
```

Figure A2. Subroutine HELIX.

# APPENDIX 3 SUBROUTINE COMED

This subroutine is listed in Figure A.3. It is used to find the plate (number) that shares corners  $C_1$ ,  $C_2$  with plate I.

#### CALL statement

CALL COMED (I,C1,C2,CR,NPLC,NCED,NALL,NOP,NOC)

#### Input:

I: plate (number) under consideration

C1,C2: position vectors of corners C1, C2. Dimension C1(3),C2(3)

CR: List of position vectors of corners. Dimension CR(NOC,3),

where the first parameter NOC is the corner index.

NPLC: List of corner indices. Each corner index carries two

parameter NPLC (NOP, J) where NOP is the plate index and J is the integer 1, 2, 3 or 4 assigned to each corner

of the 4-corner plate.

NALL>0: check out all plates (NALL plates)

NALL<0: check only the plates with index number smaller than I

NOP: total number of plates.

#### Output:

NCED>0 plate having index NCED shares corners  $C_1, C_2$  with plate I

NCED<0: no plate shares corners  $C_1, C_2$  with plate I.

```
THECK IF THY PLATES SHARING CORPERS C1802 WITH PLATE J
            INPUT: J. LI.CZ.CP. NPLC. MALL
            OUTPUT: CEL
            J: THE H OF THE PLATE WITH CURNERS CIRCS
            MCTUS U. --- THERE IS A PLATE SHARING CORNERS CINC2
                         & MEFO REPOSENTS THE # UF THE PLATE
 7 (****
                         SHARING CIRCS WITH PLATE J
 . (****
            MCENC V. --- THERE IS MO PLATE SHARING CORNERS C18C2
111 *****
            MALLS I --- CHECK OUT ALL THE ECSSIBLE PLATES SHARING
11 /****
                         THE TWO COPHERS
12 (****
           - MALLY A --- CHECH ONLY THE PLATES WITH PLATE # SMALLER
15 (****
                        THAN THE CURRENT PLATE #
14 C
         SUPROUTINE COMEDIA, CI.CZ. CR. NPLC. NCED. NALL. NOP. NOC)
10
         1 1 - E 1 5 1 0 W ( R ( NOC + 5 ) + NOPLE ( NOP + 4 ) + ( 1 ( 3 ) + ( 2 ( 3 ) + ( K ( 3 )
10
11
         P(FU=-1
1 8
         TH (MALL.LI. 0) LIEU-1
19
         TE (MALL . 61.0) LI=MALL
21
         10 1 11=1.11
21
         TH (11.E0.J) GO TO 1
23
         1= 1
25
         10 2 17=1.4
24
         12=NPLC(11.12)
25
         DU 3 15=1.3
         (K(15)=CH(L2+13)
26
15
         10 4 14=1.42
2.
         TH (14.60.2) GO TO ?
29
         10 5 15=1.5
         TETU1((5). PF . CK(15)) 60 TU 4
30
51
         6.0 10 3
30
         10 6 16=1.5
53 6
         TH (C2(16) - HE - CK(16)) GO TO 4
54
          1=1+1
         TF(1.60.2) | CED=11
55
          (F(1.66.2) 60 TO 11
56
   14
57
         CUHTINUE
30
         CUMTINUE
    .
31
         CULITINISE
41:
    10
         FLIURE
41
         1 141
```

Figure A3. Subroutine COMED.

# APPENDIX 4 SUBROUTINE IMAGE

This subroutine is listed in Figure A4. Subroutine IMAGE finds the position vector RI(3) of the image of a source vector RS(3) projected on the plate (number) I.

CALL statement

CALL IMAGE (RS,RI,I,NIMA,VNP,NPLC,CR,NOP,NOC)

#### Input:

1: plate under consideration

RS: position vector of source point

VNP: list of unit vectors normal to plate I.

NPLC: list of corner indices.

CR: list of position vectors of corners

NOP: total number of plates.

NOC: total number of corners.

### Output:

RI: position vector of image point

NIMA: image indicator

NIMA>O image exists and distinct from source

NIMA<O source is on the plate, RS=RI.

```
SUPROUTINE IMAGE ( AS. KI. JI. NIMA . VNP . NPLC . CR . NOP . NOC)
 1
 2
          PIMENSION HS(3) +RI(3), WNP(MOP+3), NPLC(MOP+4), CR(NOC+3)
 ÷
          I TWV=T
 4
          J=MPLC(J1.1)
 0
          1=0.
 6
          10 1 11=1.5
 7 1
          A=A+(KS(11)-(P(J, 11))*(MP(J1,11)
          1F (ABS(A).LT.1.E-10) HTMA=-1
 15
4
          JF (ABS(A) .[1.1.E-19) A=0.
         10 3 13=1.5
111
11 2
         :(13)=RS(14)-2.*A*V*P(J1,13)
12 4
         PETURN
13
         11.1)
```

Figure A4. Subroutine IMAGE.

## APPENDIX 5 SUBROUTINE REGION

This subroutine is listed in Figure A.5. Given a source point RRS and an observation point RRO, subroutine REGION will check if any plate is blocking the ray path. A plate does not block the ray path if either the source point or the observation point is on the plate.

### CALL statement:

CALL REGION (RRS,RRO,RRT,CR,VNP,NN1,NN2,TELL,NPLC,NFAR,NALL,MM, NOP,NOC)

Input: Position vectors of source point and observation point respectively.

CR: List of position vectors of corners

VNP: List of unit vectors normal to the plates

NN1,NN2: Blocking check of plates NN1, NN2 not required. If want to check blocking by all plates, set NN1, NN2 to negative integers.

NPLC: List of corner indices

NFAR: Far field indicator. For observation point in the far field NFAR>0

NALL: Number of plates that may block the ray path (usually NALL=NOP)

NOP: Total number of plates on structure

NOC: Total number of corners on structure

Output:

RRT(3): Position vector of point of intersection

MM: The plate (number) that first blocks the ray.

TELL: Blocking indicator

TELL=.TRUE.: A plate is blocking

TELL=.FALSE. No plate is blocking the ray.

Subroutine called is CROSSP.

```
UNKNOUTING FEATURITRES. KKO. KMT. CR. VNP. NN1. NN2. TELL. NPLC
 1
         A. M.F. AR . WALL . P. P. NOP . P. OC)
          TOUTCH THE
          -1 LESTON , RE( 1) . RES( 1) . CE ( POC. 3) . VMP ( NOP. 3) . PRT ( 3) . VE1 ( 3) . VE2 ( 3)
 11
          141 Fe 2101 1, 5131.124(0) . Wate (406.4) . 013)
 +
          P1=3.14159265
          TELL = . FALCE .
          10 12 1'=1.0011
 0
   CALLA TE PLATE IS 1801 OR BINZ DO BOT CHECK
1
          1+ (mat J. Maj. ( R. M. + ( . R. M. ) 60 TO 12
11
          1 = PL( ( -1)
          1=11.
10
15
          11=11.
14
          10 2 12=1.3
          N=N+(KES(Ic)-CR(L+12))*VMP(N,Ic)
15
          1+(1+11.01.1) 9=4+6KU(12)*VAP(N.12)
1 +
17 2
          IF (NFAP.LI.) R=++(KRO(I2)-CP(L,I2))*VNP(N.I2)
18 CA
          UNITE (6.-) ".A.B
19 (****
20
          TF (ABS(A) . L 1 . 1 . L - 10) A=0.
21
          11 (ABS(B).LT.1.E-10) 8=0.
2: (A
          R) TE (6 .- 10 . A. R
25 C**** AND GE DIOS AND U OH SAME SIDE OF PLATE
          16 (A* 3.66.() GO TO 12
24
          IF (NEAP . C.L . C) GO TO 4
25
20
          1 =0 .
          ru o 1'=1.3
27
          "(15)=RFD(1')-RRS(15)
21
24
    5
          F=F+()(15))**2
          ( = SWRT(F)
311
   4
          (1) 6 15=1.5
51
32
          IF ( MEAP . 66 . 0) D(16) = RRO(16)
55
          IF (NEAR . L.T. U) P(16)=0(16)/E
54
          (=11.
5:1
          10 7 17=1.5
34
   7
          (=C+0(17)*V+(N+17)
          00 8 19=1.3
57
          FRT(18)=KKS(18)-A*U(18)/C
36 6
39 CA
          LRITE (6.14) (RPT(I) . I=1.7)
411
          F=11.
41
          nu 9 19=1.4
42
          1=1.
40
          11=0.
44
          12=0.
45
          1=19+1
40
          TF (19.10.4) U=1
          (I=HPLC(1,14)
47
4.
          JZ=NPLC(1..U)
49 CA
          *KITE(5,-) 19,0.01,02
```

Figure A5. Subroutine REGION.

```
PO 10 110=1.3
50
         VE1(114)=CF(J1.119)-FRT(T10)
51
         WE?(110)=CF(J2,110)-PFT(110)
53
         P1=A1+(VE1(110)1**2
55
         12=43+(11+2(1)+1)**
5.4
         C=C+VE1(110)*VF2(110)
50.7
         AL=SORT(LL)
be
57
          12=SUNT (A2)
          IF (A1.1.T.1. +-(8.0F.A2. | T.1.F-6.) 60 TO 15
58
59
          CALL CROSSPIVET. VEZ . VM3. VS)
         "RITE(4.14) (VF1(1) +1=1+3)
61 11
bl CA
         FRITE (6.14) (VF2(1) .1=1.3)
6. CA
         #RITE (6.14) (CP(U1.1). 1=1.8)
         HITE (6.24) (CR(UZ.1).1=1:5)
65 CA
          WRITE (6.14) (VM5(1) .1=1.3)
64 TA
65 CA
          WRITE (6.14) (V3(1).1=1.3)
          H=0 .
61.
67
          PU 11 [11=1.3
          H=H+V2([13)*VNP(N.]11)
60 11
          FI=ATAUZ(H.G)
69
          IF (PI-ARS(FI). LI. 1. L-06) 60 TO 17
10
71
          F=F+F1
12 CA
          - KITE ( ... ) FI . G . H
          CUMTIMITE
75 9
74 14
          FURMAT(St15.5)
          WKITE (6,-)F
75 CA
          TE (ABS(F).LT.PI) GO TO 12
7 t
71
          60 TO 13
16 15
          CULTIFUE
17 CA
          WRITE (B. It) U1 . de
80 CA
          WRITE (8.15) 41.42
          CUPMAT(/'INTERFCTION PT COINCIDES WITH CORNER', 14. CR'. 14)
81 15
          FURMAT(/'A1=',F15.5,' A2=',E15.5)
82 19
83
         x • A2= • • £15.5)
84
         CU TO 13
          CONTINUE
65 17
BE CA
          PHITE (8.1F) J1.J2
          FUPMAT(/ 11 TERSECTION POINT IS ON THE EDGE DEFINED BY CORNERS!
07
    18
88
         8.14. 8. 14)
63
    13
          D. 141=1-1
41
          TELL=. TALE.
91
          60 10 3
92
    15
          CUNTINUE
93
          RETURN
    3
44
          FIVE
```

Figure A5 (Cont'd).

# APPENDIX 6 SUBROUTINE DIFPT

This subroutine is listed in Figure A.6. Given a source point RS and a near-zone observation point RO, subroutine DIFPT finds the position of the diffraction point on the edge (wedge) following the procedure described in reference 1.

#### CALL statement:

CALL DIFPT (RS,RO,C1,C2,VNN,SP,S,ANI,RD,VI,IDX,VPHNS,VPHND,VBNS,VBND,PHS,PHD,BN,E)

Input:

RS(3),RO(3): Position vectors of source point and near-field

observation point respectively.

C1(3),C2(3): Position vectors of corners C1, C2 defining the edge

VNN(3): Unit vector normal to the plate,  $\hat{\mathbf{n}}$ .

Output:

RD(3): Position vector of diffraction point Q

SP: Distance between source and diffraction point in meters.

S: Distance between observation point and diffraction

point in meters.

ANI: Angle of incidence w.r.t. the edge in radians

VI(3); Unit vector along incident ray from source to dif-

fraction point

IDX: Edge diffraction indicator IDX<O no diffraction by

the edge, vice versa

VPHNS(3), VPHND(3)  $\hat{\beta}'$ ,  $\hat{\beta}$  unit vectors (see accompanying Figure, Figure 11)

VBNS(3), VBND(3):  $\hat{\phi}'$ ,  $\hat{\phi}$  unit vectors

PHS,PHD:  $\phi',\phi$  angles in degrees.

E(3): Unit vector along edge: from corner C1 to C2, Ê.

BN(3): BN=VNNxE, unit vector perpendicular to the edge, B.

Subroutine called is CROSSP.

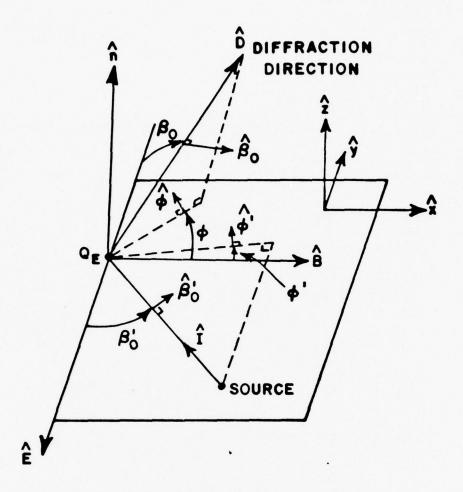


Figure 11. Unit vectors for ray-fixed coordinate system.

```
SUPROUTIFE "IFPICKS. RO. CI. CP. VNN. SP. S. AMI. RD. VI . IUX.
 1
        IVPLUS. VPERI . VENS. VEND. PHC. PHD. BU.F)
         3
         010ENS100 \PENS(3), VENMO(3), VENS(3), V( NO(3), VI(3), VD(3)
         1 10F0 5 106 40 0 (3) . VA (5) . PM (5) . B (3) . VRS (5) . VRD (3)
 0
         PATA PI. 1P/ .. 141592654 . 6 . 283165308/
         1 = 0 .
 7
         (=).
4
         · 1=0.
10
         1 == 1.
         F=SQRT((C)(1)=C1(1))**2+(C2(2)=C1(2))**2+(C2(3)=C1(3))**2)
11
12
         16 1 1=1.
         E(T) = (CP(1) - C1(1))/F
1 5
         (1=01+(C)(1)-PS(1))**>
14
         " = " = " (C. (]) - PS(1)) **2
15
         -a=(C1(1)-65(1))*6(1)
10
         (=0+(KS(I)-(&(I))*((I)
17
    1
         (1=5067(61)
10
19
         1 = SGRT(6)
         10 2 1=1.10
20
21
         54(1)=(5(1)+(*E(1)
         F=0+(RO(1)-10(I))*F(1)
20
25
         F=11.
         1. = 11 .
24
         FO 3 1=1.6
25
         #P(I)=#4(I)+W*F(I)
26
         H=H+(RS(1)-FU(T))**2
27
20
         f=6+(R0(1)=6P(T))**2
24
         JF (AUS(G).[].1.t-10.UR.AFS(H).LT.1.E-10)GO TO 5
511
         F=SWRI(H)
         C=SURT(G)
31
         V=(W*6)/(G+1)
50
         ANI=AIAHZ (G.AES(V))
33
34
         Sr=0.
         5=0.
23
         1.0 4 1=1.0
36
         60(1)=PP(1)-V*F(1)
31
         V1(1)=40(1)-PS(1)
30
         VU(I)=PO(I)-RD(I)
35
40
         SP=SP+(V)(1))**2
41
         S=S+(V)(1))**2
4,
         SP=SORT(SF)
40
         S=SWHT(S)
44
         P=0.
+5
         DU 6 1=1 .a
4+
         11(1)=V1(1)/SE
47
         March 1 = ///(1.178
48 6
         1=1+40(1)*1(1)
44
         1 5=45/11
```

Figure A6. Subroutine DIFPT.

```
50
          124=-6/32
          TE (P. GT. 43. AMP. P. GT. 441 GU TO 5
51
5.
          THIP.LT. ..... OND . P.LT. 04) GO TO 5
55
          CALL CHOSSE (VNM+E+PM+B)
54
          11=6.
55
          12=0.
56
          1.5=0.
57
          14=0.
58
          ru 10 T=1.3
59
          6.7=6.7-6.1(1)*Abb(1)
60
          DZ=P2-VI(1)*HN(I)
61
          P3=P3+V0(1)*VNM(1)
62
          F4=P4+VO(I)*BN(I)
     10
63
          (Sa. (4) 24V [V=SH4
64
          PHD=ATAM: (Pa.P4)
65
          TE (PHS.LI.U.) PHS=TH+PHS
          IF (PHO.LT.O.) PHU=HHU+TP
66
67
          10 11 1=1.5
          VPHNS(1)=COS(PHS)*VMN(1)-SIM(PHS)*BM(1)
63
64
    11
          VPRMD(I)=(U5(PHU)*VMM(I)-SIM(PHU)*BM(1)
70
          CALL CROSSF (VPHNS, VI, VBNS, VPS)
71
          CALL CROSSE (VPHNU, VO, VPND, VPD)
7:
          10x=1
75
          0010 12
74
    5
          11)x=-1
75
     12
          PETURIV
.76
          FINE
```

Figure A6 (Cont'd).

### APPENDIX 7 SUBROUTINE DIFPTF

This subroutine is listed in Figure A.7. Given a source point RS and a far-zone unit vector RO, subroutine DIFPTF finds the position vector of the diffraction point RD, if any, on the edge defined by corner C1 and C2. Relevant expressions are described in Reference 1.

#### CALL Statement:

CALL DIFPTF (RS,C1,C2,VNN,RO,SP,ANI,RD,IDX,VPHNS,VPHNS,VBNS, VBND, PHS, PHD, BN, E)

Input:

RS(3), RO(3): Position vectors of source point and far-zone

unit vector

Position vectors of 2 corners defining the edge C1(3),C2(3):

VNN(3): Unit vector normal to the plate

Output:

RD(3): Position vector of the diffraction point on

the edge.

SP: Distance between source and diffraction point

in meters.

ANI: Angle of incidence w.r.t. the edge in radians

IDX: Edge diffraction indicator; IDX<0, no diffraction

by the edge, vice versa.

 $\hat{\phi}',\hat{\phi}$ VPHNS(3), VPHND(3);

 $\hat{\beta}',\hat{\beta}$ VBNS(3), VBND(3);

PHS, PHD:

 $\phi', \phi$ 

BN(3): BN=VNNxE; also a unit vector perpendicular to

the edge.

E(3): Unit vector directing along the edge from corner

C1 to C2.

```
1
          SUPROUTING OIFPIFORS.C1.C2.VNN.VD.VI.SP.ANI.RD.IDX.VPHNS
         S. VPHIND . VMINS . VRND . PHS . PHD . EN . F )
 2
         FIMENSION ES(3),C1(3),C2(3),RD(3),RD(3),E(3)
 3
          01 MENSION: \ PUNS(3) . VPHNO(3) . VBNS(3) . VBNO(3) . VI(3) . VD(3)
 4
         01MENSION VAN(3).VES(3).VS(3).VS(3).F(3).VBS(3).VBD(3)
 6
          PATA PI. 18/3.14159, 654.6. 283185308/
 7
          C=0.
 8
          02=U.
          F=SGRT((L2(1)-C1(1))**2+(C2(2)-C1(2))**2+(C2(3)-C1(3))**2)
 9
11
          00 1 1=1.5
          F(1) = (02(1) - 0)(1)1/F
11
12
          12=42+(H5(1)-C1(11)**2
13
          6=0+(ES(1)-CI(I))*f(I)
14
          HZ=SURT(HZ)
          CALL CROSSP(VD.E.VP3.V3)
15
16
          H=0.
17
          0=7.
         FP=0.
10
19
          00 2 1=1.3
20
          F=F+(RS(1)-C1(I)-U*E(I))**2
21
          RG(1) = C1(1) + G*E(1)
22
          P=P+VU(I)*E(I)
          FP=PP+V3(1)*VN3(1)
25
    2
24
          TF (ABS(H).L1.1.E-10) GO TO 5
25
          H=SGRT(H)
26
          IF (AHS(PP).LT.1.E-10)GO TO 5
          ANT=ATANZ(FF.P)
27
          h=H*COS(ALI)/SIN(ANI)
26
29
          FI=U.
50
          13=U.
31
          SF=9.
32
          DU 3 1=1.5
35
          RU(I)=RU(I)+U*E(I)
34
          VI(1)=RO(1)-RS(1)
35
          61=H1+(C2(1)-ES(1))*E(1)
34
          F3=E3+(C2(I)-RS(I))**2
57
    3
          SP=SP+(VI(I))**2
          TH (SP.FO. 0.) GO TO 5
31
39
          SP=SQRT(SP)
411
          P3=SORT(U3)
41
          IF (AMI.LI.O.) ANI = ABS (AMT)
40
          P1=P1/P5
45
          P4=-0/82
44
          1F (P. GT. E1 . AND . P. GT. 84) GU TO 5
          IF (P.LT. 61. (NO.P.LT.64) GU TO 5
45
40
          nu + 1=1.3
47
          V1(1)=V1(1)/SP
40
          CALL CROSSF (VMM . F . PN . B)
49
          P1=0.
```

Figure A7. Subroutine DIFPTF.

```
P2=0.
511
51
         F 3=0 .
         F4=0.
5.
55
         00 10 1=1.3
         P1=P1-V((1)*WMH(1)
54
         (1) MH*(1) 7-59=54
CC
         P3=P3+VD(I)*VpM(1)
50
         P4=P4+V0(1)*RN(1)
57
   10
55
         PHS=ATAME(F3,P2)
         PHO=A (ANZ (FS,P4)
5 1
         IF (PHS.LI.A.) PHS=TP+PHS
611
61
         TE (PHO.LT.C.) PHC=TP+PHO
         PHO1=PHO*1FO./PI
60 CA
63 CA
          PHS1=PHS*160./PI
         PRITE(6.15)[HS1.PHO1
64 14
65
   1 2
         FURMAT(4) +4615.5)
6+
          10 11 1=1.0
          VPI MS(I)=(65(PHS)*VMM(I)-$1M(PHS)*BM(1)
61
          vPants(I)=(05(PHO)*van(I)-SIN(PHD)*BN(I)
E.F.
    11
          CALL CROSSPIVPHMS . VI . VRNS . VRS)
69
          CALL CROSSP(VPHME+V9+VFMQ+VPM)
19
71
          10)=1
12
          60TO 12
75
   5
          10x=-1
74
   12
          RETURN
75
          FISH
```

Figure A7 (Cont'd).

# APPENDIX 8 SUBROUTINE WEDIFF

Subroutine WEDIFF is listed in Figure A-8. Given a source point RS and an observation point RO in the far-field (NFAR>0) or near-field zone (NFAR<0), subroutine WEDIFF generates relevant parameters for the computation of the diffracted field in the presence of the edge defined by corners C1 and C2.

#### CALL statement:

CALL WEDIFF (RS,C1,C2,RO,RD,IPL,NFAR,AM,WAVM,NCM,VNP,CR,NPLC,NOP, NOC,VBNS,VPHNS,CONS1,VB2,VB2,IDIF,VBND,VPHND)

Input:

RS(3),RO(3): Position vectors of source point and observation

point

IPL: Plate under consideration

NFAR: Far field indicator

AM: Wire radius in meter WAVM: Wavelength in meter

NCM: Size of the compressed matrix

VNP: List of unit vectors normal to the plates

CR: List of position vectors of corners

NPLC: List of corner index

NOP: Number of plates
NOC: Number of corners

C1,C2: Corners C1 and C2 defining the edge

Output:

VBNS(3), VPHNS(3): Unit vectors  $\hat{\beta}', \hat{\phi}'$  (Figure 11) VBND(3), VPHND(3): Unit vectors  $\hat{\beta}', \hat{\phi}$  (Figure 11)

IDIF: Diffraction indicator

CONS1:

Diffraction coefficient

VB1, VB2:

 $V_B(L,\beta^-,n), V_B(L,\beta^+,n); \beta^{\pm}=\phi\pm\phi^{\dagger}$ 

such that

$$E_{..}^{d} = -(VB1-VB2)*E_{..}^{i}*CONS1$$
  
 $E_{..}^{d} = -(VB1+VB2)*E_{..}^{i}*CONS1$ 

Phase of  $E_{u}^{d}$  and  $E_{u}^{d}$  is referred to origin of coordinate system when NFAR>0, to source point when NFAR<0. Subroutines called DIFPT, REGION, DIFPTF, COMED, CROSSP.

```
1 C**WEDCE DIFFRACTION
          SUFROUTTHE SECTEF (PS.C1.r2.RO.KO.IPL.NFAR.AM.WAVM.NCM.VNP.
          ECR . MPLC . MOP . NOC . VENS . VPI MS . CONSI . VB1 . VR2 . IDIF .
          · Vurin . VPhill 1
 +
          IUGICAL IFLL
          DIMENSION PRP(NOP. 3) - DPEC(NOP. 4) - CR(NOC. 3) - VNN(3) - VN(3)
 5
 7
          PIMENSION FAT(3) . RS(3) . Rn(3) . C1(3) . C2(3) . RD(3) . VI(5)
          PINENSION VEHNS(3). VEHND(3). VBNS(3). VBND(3). BN(3). E(3).
 3
 9
          8EDN2(3) + BM2(3) + V3(3) + VM3(3)
1:)
          COMPLEY VEL. VP2. CONSI
          MATA TP/6.2131855/.PI/3.14150205/
11
          PU 31 T31=1.3
12
13
    31
          V.Vr (151)=Vr P(IPL+131)
          TPL=TP/NAVE
14
15
          TUIF=L
10
          010=103.//1
          1+ (NFAR. 67. 6) 60 10 49
11
1
          TALL DIEPT(HS. RO.CI.CZ. VMM. SP. S. ANI. RU. VI. IDX. VPHNS.
19
          XVPHND.V6NS.VRND.PHS.PHD.BN.F)
          IF (IDX.EG.-1) GO 10 22
20
          CALL REGION (ES. KU.RKT.CR. VNP. - 1. - 1. TELL, NPLC. - 1. NOP.
21
22
          FMM . MUF . MUC)
23
          IF (IETT) 60 10 55
44
          CALL REGION (MO. KU. FKI. CR. VMP. - 1. - 1. TELL. NPLC. - 1. NOP.
25
          PHM . NOF . NOC )
20
          1+ (TELL) 60 TO 22
27
          60 TO 42
          TALL DIFFTE (KS.C1.C2.VAN.RO.VI.SF.ANI.RO.IDX.VPHNS.
211
    4.1
          SABHUT. APPS . ADMO. SHED. PHD. PW. E.J.
29
50
          TF(10x.FC.-1) 60 10 22
          CALL REGION (PS. KD. RKT. CR. VMF. - 1 .- 1. TELL . NPLC .- 1. NOP
51
30
          O . MM . NOP . NOC)
33
          TECTELLI GO TO 22
34
          CALL REGION (ROAKOAPKTACKAVAPA-1.-1.TELLANPLC.1.NOPA
35
          SMM . HUP . HULL
30
          IF (TELL) GU TO 22
37 C** CALCULATE WEITHW ANGLE
          TALL COMED (1PL . C1 . C2 . CR . NPLC . NCED . NOP . NOP . NOC)
30
    42
          IF ('NCED-0)34.34.35
53
40
    54
          1111=2.
41
          60 TO 36
42
    35
          nu 37 137=1.3
43
          EUM2(137)=-F(137)
44
    37
          VIN(137)=VEP (NCED+137)
45
          CALL CHOSSPIVN, EUNZ . BMZ . V3)
46
          CALL CHOUSE (BM . BN2 . VN3 . V3)
41
          AA1=0.
40
          EA2=0.
          TO 38 150=1.3
44
```

Figure A8. Subroutine WEDIFF.

```
LA1=AA1+LA(13E)*BA2(13E)
50
          AA2=AA2+V 3(139)*V3(138)
    34
51
          INTER-SAADSHATADORA-.AMI))/PI
5
          AL=(PH)-+HS)*RTD
55
          12=(PH*+PH*)*DTD
74
          1. (JE 15 .. 1.1) GU 10 59
5:
          1 L L L = SI + S + ( E IN ( AN I ) ) * * 2/( (SF+S) * WAVM)
20
          10 10 04
71
          *FINE=SP*(210(VMI))**5/MVM
    31
51
          CALL VILLATIVE . TYP . AL . L . A1 . W.
    411
2..
          WHITECHPL'S (FVH, TVH)
61.
          CALL VEILVE . TVR . AL . L . AZ . WIN)
6.1
          VETECHTLA (LVP. TVE)
60
          15=11.
63
          10 17 11/=1.3
64
          AS=AS+(RE(117))*FO(117)
    17
5
          1F (NFAK . 61 . 6) 60 10 25
oth
          CUES1=(SE/(SP+9))*CEXP(CMPLX(0.,TP*(ALWL-S/WAVM)))
51
          (0 TO 21
614
          rubS1=(St)*C+xP(CMPLX(0..]P(*(Sp*(SIM(ANI))**2+A3)))
67
111
          10 TO 21
71 22
          11.11=1
          FLTURIS
12 21
1:
          FIVE
```

Figure A8 (Cont'd).

# APPENDIX 9 SUBROUTINE CSORT

This subroutine is listed in Figure A.9. It is used to set up the image points and image segments, generate ID indices for these points and segments, derive the size of the compressed impedance matrix, set up the modes and provide a list of modes MD(J,K) and a list of dipoles ND(J) sharing segment J. Basically CSORT is a modified version of subroutine ISORT in reference 2 to deal with wire antennas on different plates of the satellite structure. Input data for the satellite structure are entered through the last seven parameters in the CALL statement, namely VNP,NPLC,CR,NOP,NOC, IDSEG,IDPT. Output parameters are NCM,IDSEG,MD,N,DC,I1,I2,I3,IA(K), IB(K),XC(I),YC(I),ZC(I).

#### CALL statement:

CALL CSORT (IA, IB, ICC, ICJ, INS, IWRITE, I2, I2, I3, JA, JB, MAX, MIN, MD, N, NCM, ND, NP, NS, NRP, NRS, NPGP, NSGP, DC, XC, YC, ZC, VNP, NPLC, RC, NOP, NOC, IDSEG, IDPT)

The above parameters are defined as follows:

### Variables

Input:

IA(J), IB(J):
End points index of segment J extending from

A to B

ICC: Dimension relating to matrix C(I,J)

ICJ: Dimensions relating to the number of dipole

modes N

INP: Dimension relating to the number of points

NP

INS: Dimension relating to the number of segments

NS

XC,YC,7C: Coordinates of real points in meters

NRP: Number of real points
NRS: Number of real segments

NPGP: number of points touching the ground plane

(plates)

NSGP: Number of segments with end points on the

plates

NP: Number of points for the complete antenna

system

NS: Number of segments for the complete antenna

system

VNP, NPLC, CR, NOP, NOP: Parameters relating to satellite structure

as defined previously

Output:

NCM: Size of the compressed matrix

ND(J): List of dipoles sharing segment J

MD(J,K): List of dipole modes sharing segment J

N: Number of dipole modes of the complete system

 $I_1, I_2, I_3$ : Terminal point  $I_2$ , end points  $I_1$ ,  $I_3$  of dipole

modes

XC,YC,ZC: Coordinates of imaginary and real points IA,IA: End points of real and imaginary segments

JA, JB: Segment number for each dipole mode

DC: Segment length in meters

IDSEG(K); Plate that accommodates segment K
IDPT(I): Plate that relates to endpoint I

Subroutine called IMAGE.

Output: Size of the compressed matrix NCM: List of dipoles sharing segment J ND(J): List of dipole mode sharing segment J Number of dipole modes of the complete system MD(J,K): <N> Terminal point  $I_2$ , end points  $I_1$ ,  $I_3$  of dipole I<sub>1</sub>, I<sub>2</sub>, I<sub>3</sub>: XC,YC,ZC: Coordinates of imaginary and real points IA, IA: End points of real and imaginary segments Segment number for each dipole mode Segment length in meters JA, JB: DC: Plate that accomodates segment K IDSEG(K); Plate that relates to endpoint I IDPT(I):

Subroutine called IMAGE.

```
1
          ASC SHOLLAD
          SUPROUTINE CSOPT(IA . IR . ICC . ICJ . I; S . IWKITE . I] . 12 . 13 . Jn . Ju .
 2
          SMAX. MIN. MP. N. NCM. NO. NF. MS. NRP. NRS. MPGF. NSGF. DC. XC. YC. 2C.
 4
          FULP + MPLC + CH + NOP + MGC + IDSFG + IDPI)
          01-ENSION JSP(20) +00(1) +xc(1)+10(1) .ZC(1)
 5
          "IMENSION II(1) . IZ(1) . IZ(1) . JA (1) . JR(1)
 6
          -1 MENSION YER (MOP+3) + HELT (MOP+4) + CRIMEC+3) + ES (3) + E1 (4) + I; SEG (65)
 1
          MENSION ILPT(70)
 3
          ~ I ME MS101 IN(1) . IB(1) . MD(1) . MD(105.4)
 54
10
    1
          E OPPHAT (5入・*い*・1X・*TA())*・1X・*10())*・3X・*PLATE*・4ノ・*ド・・
11
          * 1 x . • [ A ( F ) • . 1 X . • [ B ( K ) • . 1 Y . • P[ A [ F • . 1 X . • DC ( J) • )
          FORMAT(12.315.79.16.215.76.2F1J.5)
12
          FORMALITA.115,3110.0.115.3510.0)
13
    4
14
          FURMAT(1X, FIE, 1115, 615)
15
    5
          FUPMAT(1Ha)
          FURMAT(54.11.4X. xC(I). 5x. YC(T). 57.26(I).
10
    6
          ( *(b) 75', xd. *(b) 7Y', xe. *(b) 7X', x,, *U', xe.
11
          FURMAT(5X+11+3X+1UA1+3X, 1UB1+3X+1121+3X+1121+3X+123++
16
19
          2147. * K 1.3x . 1 d 2 . 3y . 1 d 1)
20
          16PP=HPGP+1
21
          WPT=MXP-MPH
     WEXT CET UP THE IMAGE SEGMENTS
22 r
23
          10 18 J=1.N48
24
          K=J+NKS
25
          TA(K)=TA(J)
          IF(IA(J).67.0P(P)I/(K)=IA(J)+MPI
20
27
          18(K)=IB(J)
          1+(IB(J).6T.(PAP)10(K)=ID(J)+NF1
24
   10
SA L WEXT SET OF THE IMUGE BOTHLE
30
          PU 20 I=IGFF NRP
31
          J=I+MPI
35
          85(1)=XC(1)
33
          55(2)=YC(I)
54
          PS(3)=20(I)
35
          JUPTI=IDPT(I)
          CALL IMAGE (RS.RI. 10P1I. NTMA. VNP . MPLC. CK. NOP. NOC.)
36
31
          YC(J)=P1(1)
          YC(J)=R1(2)
30
39
          70(J)=P1(5)
    27
411
          10PT(U)=10PT(I)
41
          10 21 1=1.108
42
          IAI=IA(I)
45
   21
          TUSEG(I)=IUPT(IAI)
44 C PEXT CALCULATE THE SEGMENT LENGTHS DOLL)
          TE (IWRITE . LF . 0) GU TO 22
43
46
          URTIE (6.5)
47
          URITE (6.1)
          10 25 J=1.NES
40
    22
49
          (L)AT=N
50
          [=]B(J)
51
          DX=XC(K)-XC(L)
56
          PY=YC(K)-YC(L)
53
          DZ=ZC(K)-ZC(L)
54
          C(J)=SURF(UX*DX+OY*OY+DZ*UZ)
55
          K= J+NKS
```

Figure A9. Subroutine CSORT.

```
56
           CC(K)=DC(U)
 57
     25
           TF(IWRITE.GE.1)WRITF(6.2)J.TA(J),18(J).IOSEG[J).K.AA(K).IB(K).
 50
           & IT SEG(K) . IC(J)
           IF ( I WRITE . LE . O ) GU TO 32
 59
 60
           PHITE (6.5)
 61
           WHITE (6.6)
 62
           10 30 I=1 . MEP
 63
           IF (1.6T.NP6P)60 TO 20
 64
           WRITE(6.3)1.XC(1).YC(1).7C(1)
 65
           60 TO 30
 66
     29
           J=I+NPI
 67
           WRITE(6.5)[.XC(I).YC(I).ZC(I).J.XC(J).YC(J).ZC(J)
     30
 68
           CONTINUE
 69
           WRITE (6,5)
 70 C
       CHECK INPUT DATA FUR CONSISTENCE
 11
     32
 72
           M1N=100
 73
           MAX=100
 74
           IF (NPGP.LE.C)GO TO 40
 75
           1.0 33 1=1.NPGP
 16
           1=0
 77
           nu 35 J=1. RSGP
 78
           (1-(L) RI)*(I-(L) AI)=X
 74
     35
           IF (K.EG.U)L=L+1
 118
           IF (L.GT.MAX)MAX=L
 81
     38
           H=M+2+1.-1
 82
     411
           IF (NRP.LE. MPGP) GO TO 50
 83
           110 46 T=16PP+NRP
 84
           1 =0
 c3
           70 44 J=1.NFS
 86
           K=(I\Lambda(J)-I)*(IR(J)-I)
 87
     411
           TF (K.ER.C) L=L+1
 88
           TF (L.LT. MIN) MIN=L
 89
     45
           U=N+2*(L-))
 90
     50
           TF(N.LE.L .OR. N.GT.ICJ)GO TO 506
 91
           THIMAX.LE.G .OR. MIN.LE. P. SO TO SOU
 92
           IFINPGP.LE.0)GO TO 58
 93 C
        SET UP THE MODES AT THE GROUND PLANES THAT WILL NOT HAVE IMAGES
 94
           10 56 T=1. MPGP
 95
           0=0
 96
     52
           J=J+1
 97
           IAJ=IA(J)
 98
           IBJ=IB(J)
 99
           FK=(IAJ-I)*(IBJ-I)
100
           TF (U.EQ. MSUP)GO TO 54
           TECKK . NE . 0 ) 60 TO 52
101
102
     54
           UAII)=J
103
           JB(I)=J+NRS
104
           12(1)=1
105
           11(I)=IAJ
106
           IF (IBJ.E@.I) I1 (I)=IAJ
107
     56
           15(1)=11(1)+MPT
108
     5.4
           T=1. PGP
109
           M=MPGP
110
           M'CM=MPGP
```

```
111
           JPP=0
112
           TE (NRS. FU. I PGP) GO TO TE
113 " SET UP THE REST OF THE REAL MODES
114
          10 65 K=1. NPP
115
           MUKEU
116
          00 60 J=1.MKS
117
           IND=(IA(J)-K)*(IF(J)-K)
118
           IF (IMD. ME. 0) 60 10 60
117
           MUK=MUK+1
120
           JSP (NUV)=J
121
    611
           CUNTINUE
122
           MOD=NUK-1
123
           TE (MOP.LE.C) GO TO 65
124
           DO 65 1110=1 . MOD
125
           T = I + 1
120
           IPU=IMU+1
127
           JAT=JSP (IML)
128
           IAL=(I)AL
129
           JBI=JSD (LPD)
130
           JB(1)=JAI
131
           (1AC) \Lambda I = (I) I I
13-
           IF (IA(JAI).EG.K)II(I)=IR(JAI)
133
           12(1)=K
134
           T3(1)=I1(UBI)
135 62
          TF (IA (JP1) . + 0.K) I3(I) = IB (JBI)
136
     65
          CONTINUE
157
          V.C ~= I
130
          OFF = NCM - NFGF
139 r
       MEAT SET UP TH IMAGE MOLES
140
          DO 70 I=IGPP . NCM
141
          K=1+JPF
142
           JA(K)=JA(I)+HRS
145
           JB(K)=JB(I)+NPS
144
           T1A=11(1)
145
           (1)SI=011
          110=13(1)
146
147
          11(K)=11A
148
          IF(IIA.GT.FPGP)II(K)=IIA+HPI
149
           12(K)=118
150
          If (IIB.el.Wbeb)IS(K)=IIB+Wbl
151
           13(K)=11L
150
     71
          IF (IIC.GI.NPGP) I3(K)=IIC+NPI
153
          M=2*NCM-NPGP
    75
154
          MAYEU
155
          MIN=109
150 ( HIP (J) = HUMBER OF DIPOLE MODES SHARING SEGMENT J
157 r MO(J.K)=LIST OF DIPOLE SHARTER SEGMENT J
150
          10 100 J=1,05
159
           no 80 K=1.4
160
    00
           MU(J.K)=0
161
          K=C
           00 90 I=1.1
162
165
           JAT=JA(1)
164
           JEI=JE(I)
165
          (-[80]*(U-]ab]-J)
```

```
IF (L.NE.0) 60 TO 90
16h
167
          F=K+1
168
          1=(N.C)(M
169
     91
          CONTIGUE
170
          NU(J)=K
1/1
          TH (K.ST. MAX)MAX=K
172
     100
          IF (K.LT.MIN)MIN=K
          TECIMETTE . LE . G) GO TO 500
173
174
          VKTTE (6.7)
17
          10 110 I=1.NCM
          1F (I.GT. BPGF)60 TO 108
175
177
          11KTTE(6.4)1.JA(1).JB(1).T1(T).12(1).T5(T)
178
          60 TO 110
179
     108
          K=I+JPP
          1 RITE(+4)].JA(I].B(I).J1(I).I2(I),I3(I),K,JA(K).JR(K).
160
          F11(K) + 12(K) + 13(K)
181
          CUMTIBUE
182
     110
185
          URITE (6,5)
184
     500
          FETURN
185
          FND
```

Figure A9 (Cont'd)

## APPENDIX 10 SUBROUTINE CMATX

Subroutine CMATX is listed in Figure A.10. It computes C matrix for a general wire configuration similar to subroutine IDANT and ZGS of reference 3, but CMATX also accounts for the components of the C matrix due to reflected and diffracted fields from plates and wedges as expressed in the P(I,J) terms. In the form listed, CMATX does not include effects of wire conductivity. However, if wire surface impedance is to be included, CMATX can be extended by adding the section from statements 200 and 260 of subroutine IDANT<sup>3</sup> before statement 262 of CMATX.

#### CALL statement:

CALL CMATX (ICC,INT,JPP,MD,N,NCM,ND,NLF,NP,NPGP,NRS,NS,AK,CMM,D,FMC,CDK,SDK,NFAR,WAVM,AM,XC,YC,ZC,CR,VNP,NOP,NOC,NSGP,NPLC,X,Y,Z,IDSEG)

Input and output parameters are defined below.

#### Input:

ICC Dimension related to the open-circuit impedance matrix C

INT: Integer denotes the number of integration intervals using

Simpson's rule. For general purpose set INT=4

JPP: Number of modes that have images

MD: List of dipole modes sharing segment J

N: Total number of dipole modes

NCM: Dimension of the compressed C matrix

ND: List of dipoles sharing segment J

NLD: Number of lump loads

NP: Number of points

NPGP: Number of points on the ground plane

NRS: Number of real segments

NS: Number of segments

AK:  $(2\pi/\lambda_0)$  a where a is wire radius

CMM: Wire conductivity in megamhos/m

D: List of dimensionless segment lengths kd

FMC: Frequency in MHz
NFAR: Far field indicator

WAVM: Wavelength in meters

AM: Wire radius in meters

XC, YC, ZC: Coordinates of the end points

CR: List of position vectors of corners in meters

VNP: List of unit vector normal to the plates

NOP: Number of plates
NOC: Number of corners

NSGP: Number of segments on the ground plane

NPLC: List of corner indices

XC, YC, ZC: Dimensionless coordinates of end points

IDSEG: List of plates (numbers) that act as a ground plane for

segment J.

Output:

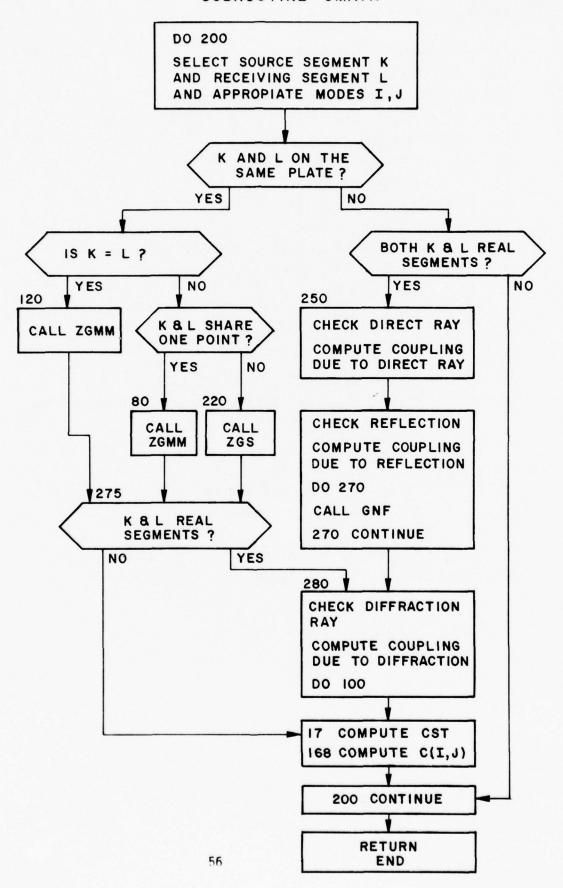
CDK: List of  $cos(\gamma d)$  for all segments

SDK: List of  $sin (\gamma d)$  for all segments

C: Resultant C matrix

Subroutine called: ZGS, ZGMM, REGION, IMAGE, COMED, WEDIFF

### SUBROUTINE CMATX



```
OPTIONS SEK
 2 C*+COPPUTE C MATHIX FOR GENERAL WIPE CONFIGURATION
 3 C**STATLAR TO IDANTE ZOS. BUT ACCOUNT FOR REFLECTION
 4 C**AND DIFFRACTION OF PLATES AND WEDGES. D.L.DOAN
          SURKOUTINE CHATX(100.INT.JPP.MD.N.NCM.NO.
 5
          RINE U. NE . NPGP . NRS . NS . AK . CMM . D . FMC . CDK . SUK . NFAR . WAVM .
 to
          *AM.XC.YC.ZC.CP.VNF.NOP.NUC.NSGP.NPLC.X.Y.Z.IDSEG)
 7
          CUMMON/COM/C
 41
 9
          CUMMON/CUM2/CGD.SGC.DC
10
          COMMON/CUM3/IA. 18. JA. JP. T1. I2. I3
11
          COMMON/COME/VG.ZLD
12
          COMMON/CUM7/P.Q
         LUCICAL TELL
13
          CUMPLEX VI (136) . ZLH (130)
14
          CUMPLEX EXI. LY1. EZ1. EX2. EY2. FZ2. GAM. SGD(65). CGD(65)
15
          8.5GDS.SGDT.CST.P11.P12.P21.P22.ETA.Q(2.2).CGDS
16
          COMPLEX P(2.2) CIJ. VH1. VR2. CONS1. EDS. EDH. EIS. EIH. QG(2.2)
17
          COMPLEX C(32.32).ET1.ET2.E11.E12.ER1.ER2.ED1.ED2
16
19
          COMPLEX H11+R12+R21+R22
20
          DIMENSION VK (3) . VMA (3) . VA (3) . IUSEG (65)
21
          01MENSION XC(70).YC(70).ZC(70), TA(65).IR(65).ND(65).CDK(65).
22
          9SDK(65)+D(65)+X(70)+Y(70)+Z(70)+DC(65)
23
          nimension 11(70).12(70).13(70).JA(70).JP(70).MD(65.4)
24
          MIMENSION UMP(MOP+x)+MPLC(MOP+4)+CI(MOC+3)+VMN(3)+VM(3)
21.
          TO IMENSION RRT1(3) * FRT(3) * RS(3) * RSA(3) * RSR(3) * RIA(3) * RIB(3) *
26
          RRO(3)+CI(3)+C2(3)+RU(3)+VI(3)+BN(3)+E(3)+V3(3)+VN3(3)
27
          DIMENSION VPHNS(3). VPHND(3). VBNS(3). VBND(3). FDN2(3). BN2(3)
28 C**(I) = TOTAL NO. OF DIPOLE MODES SHARING SEGMENT J
29 C**MP(J.K)=LIST OF DIPCLES SHARING SEGMENT J
SO C**M=TOTAL NO. OF DIPOLE MODES
31 r**
32
          DATA TU/6.28318/
33
          FORMATIRX, *Ak=*.F8.6.5X, *UMAX=*.F8.4.5X, *DMIN=*.F8.4)
    5
54
          TPL=TP/WAVE
35
          CAM=CMPLX(0. . TPL)
36
          FTA=(376.727.0)
          FI=3.10159265
37
38
          00 10 I=1.NCM
39
          DO 10 J=1.NCM
40
    10
          (0.,.0) = (0.,.0)
41
          MMAX=U.
42
          PMIN=11.0.
43
          10 20 J=1.11FS
44
          10)U=U1
45
          IF (DJ.GT.CMAX) DMAX=DJ
46
          TF (DJ.LT.DFIN) DMIN=DJ
47
          CDK (1)=COS (04)
40
          SUK (U) = SIM (UU)
          SGP (J) = CMPL x (0 . . SOK (J))
49 r
          (AU(7)=CLEFTA(CUK(9)*0*)
50 r
51
          K=J+NKS
51
          CUK (K) = CUK (J)
33
          SUK (K)=SUK(U)
54 C
          SGD(K)=CMPLX(D. . SDK(K))
55 r
          CUD(K)=CMPL>(CDK(K)+0.)
```

Figure A10. Subroutine CMATX.

```
56
     20
           CONTINUE
 57
           TE (DMIH.LT.AK) GO TO 21
 54
           TE (DMAX. 61.3.) GO TO 21
 59
           JF (AK.GT.0.1)CO TO 21
           EU TO 22
bil
           WRITE (6.2) AK . DMAX . DMIN
     21
 01
 6
           11=0
 63
           RETURN
     20
 64
           no 200 K=1.NS
 6:
           NOK=NO(K)
           KA=IA(K)
 66
           KB=IB(K)
 67
68
           DK=D(K)
 69
           SGDS=CMPLX(0.,SDK(K))
 70
           CGDS=CMPLX(CDK(K).0.)
 71
           no 200 L=1.NS
 72
           MUL=ND(L)
 73
           ( I) A=IA(I)
 74
           LB=IB(L)
 75
           DL=D(L)
 76
           SGOT=CMPLX(0.,SDK(L))
 77
           MIL=0
 78
           DO 200 II=1.NDK
 79
           J=MD(K.J1)
 80
           1E(1.51.0CM)GG TO 200
 81
           F1=1.
 82
           JF (KB.EQ.12(1))60 TO 36
 83
           IF (KB.EQ. I1 (I)) F1 =- 1.
 84
           TS=1
85
           GU TO 40
           TF(KA.EQ.13(1))FI=-1.
 86
     35
 87
           15=2
 88
     40
           DO 200 JUE1. MPL
 89
           J=MD(L.JU)
           JF (I.GT.J)60 TO 200
 90
 91
           FJ=1.
           IF(LR.EQ.12(J))60 TO 46
 92
 93
           TF(LB.50.11(J))FJ=-1.
 94
           JS=1
 95
           GO TO 50
 96
     46
           TF(LA. FQ. 13(J)) FJ == 1.
 97
           JS=2
     50
           IF (NIL. NE. 0) 60 TO 168
 98
 99
           NIL=1
100 C**PEGINNING SIMILAR TO ZGS
           CA=(X(LB)-X(LA))/DL
101
102
           CB=(Y(LB)-Y(LA))/DL
           CG=(Z(LP)-Z(LA))/OL
103
104
           INS=2*(INT/2)
105
           TF (INS.LT.2) INS=2
106
           1P=1HS+1
107
           DELT=DL/INS
108
           T=0.
109
           P11=(0...U)
110
           P12=(0...0)
```

Figure A10 (Cont'd)

```
111
           P21=(U.,.U)
           P22=(U...U)
114
115
           H11=(U. . . 0)
114
           D12=(U...0)
-15
           H21=(U.,.U)
116
           P22=(0.,.0)
117
           0(1.1)=(0...0)
118
           0(1.2)=(0...0)
119
           c(2.1)=(C...O)
120
           0(2.2)=(0...0)
           S6M=-1.
121
122 C**LIFT UP 14E SOURCES CORRESPONDING TO ENDPOINTS TOUCHING THE
123 C**GROUND PLANE FOR REFLECTION AND DIFFRACTION TESTS.
124 C**AFAC. OFAC ACCOUNTS FOR GRAZING INCIDENCE
125
           TE (KA.GT. NPGF .AND. KB.GT. NPGP)GO TO 210
126
           IF (KB.LE.NEGP) GO TO 208
127
           TUSEGK=IUSEG(K)
           PSA(1)=XC(KA)+1.E-06*VNP(IUSFGK.1)
128
129
           RSA(2)=YE(KA)+1.E-U6*VMP(IUSFGK.2)
130
           RSA(3)=20(KA)+1.E-06*VNP(1USFGK.3)
131
           RSP(1)=XC(KR)
132
           RSP(2)=YC(KE)
133
           PSP(3)=ZC(KR)
134
           AFAC=0.5
135
           PFAC=1.
136
           60 TO 215
157
      308
           TUSEGK=IUSEG(K)
130
           PSA(1)=X((KA)
139
           PSA(2)=YC(KA)
 40
           RSA(3)=ZC(KA)
141
           RSP(1)=XC(KB)+1.E-06*VNP(IUSFGK.1)
142
           PSR(2)=YC(KP)+1.E-U6*VNP(IDSFGK.2)
145
           RSB(3)=ZC(kt)+1.E-06*VNP(IDSFGK.3)
144
           AFAC=1.
145
           PFAC=0.5
146
           60 TO 215
147
           FSA(1)=XC(KA)
      210
148
           PSA(2)=YC(FA)
149
           PSA(3)=ZC(KA)
150
           PSP(1)=XC(KP)
151
           PSP(2)=YC(KE)
152
           PSP(3)=20(kB)
153
           AFAC=1.
154
           PFAC=1.
155
           CAS=(X(Kb)-X(KA))/DK
156
           CRZ=(A(KR)-A(KV))\DK
157
           CGS=(Z(KB)-Z(KA))/DK
           CCC=CA*CAS+CB*CBS+CG*CGS
158
           IUN=IUSEG(K)-INSEG(L)
159
160
           TE (100.NE.0)60 TO 240
161
           IE (K.E.O.L) CO TO 120
           IND=(\Gamma A-k V)*(\Gamma B-k B)*(\Gamma A-k B)*(\Gamma B-k V)
162
163
           TF(IND.FG.6)GO TO PO
164 C**ANTENNA SEGMENTS ON SAME PLATE
165
      220 CALL ZGS(X(KA).Y(KA).Z(KA).X(KB).Y(KR).Z(KB).X(LA).Y(LA).
```

```
160
           22(LΔ).X(LB).Y(LB).Z(LB).AK.NK.CDK(K).SNK(K).DL.SDK(L).INT.
167
           14(1,1),4(1,2),0(2,1),4(2,2))
160
          60 10 275
     120 0=0.5
169
170
          IF (KA. "E.LA) S=-0.5
          CALL ZEMP(. U.DK.DK. (.5-S). UK. (.5+S). AK. CDK(K). SDK(K).
171
172
           $50K(K) +1 . 0 +0(1+1) +0(1+2) +0(2+1) +0(2+2))
175
          00 In 275
174 C**SEGMENTS & AND L SHAKE ONE POINT
175
     Br
          K 6=0
176
          JM=KB
177
          JC=KA
178
          FF=1
179
          IND=(KH-LA)*(KR-LH)
180
          TF (INU.NE.0) GO TO 82
181
          JC=KH
182
          KF=-1
183
          . IM=KA
184
          46=3
185
    02
          16=3
186
          JP=LA
187
          1 F=-1
188
          IFILE . FG . JC 160 TO F3
189
          JP=LR
190
          1 F=1
191
          16=0
192
    83
          SUM=KF*LF
193
          (MU)Y)*((JU)Y-(QU)Y)+((JU)X-(MU)X)*((JU)X-(QU)X)]=1847
194
          8-Y(UC))+(Z(UF)-Z(UC))*(Z(UM)-Z(UC)))/(DK*DL)
195
          CALL ZGMM (. U. DK . . O. DL . AK . CDK(K) . SDK(K) . SDK(L) . CPSI
196
          8,84(1.1),60(1.2),60(2.1),60(2.2))
197
          00 98 KK=1.2
198
          KP=IABS(NK-KG)
199
          no 98 LL=1.2
200
          IP=IABS(LL-LG)
201
          O(KP.LP)=SGN+QQ(KK.LL)
202
          CONTINUE
    94
203 C*+ AMTERNA SEGMENTS PELONG TO THE SAME PLATE
204 C**IF NOTH KEL ARE REAL SEGMENTS. CONSIDER DIFFRACTION EFFECTS
205
          TE(K.LE.NRS . AND. L.LE.NRSJED TO 280
    275
206
          GU TO 17
207 C**FEACH HERE IF SEGMENTS ARE ON DIFFFRENT PLATES
306
          TECK.LE. HRS . AND . L.LE. NRSIED TO 250
209
          1105 OT 05
210 C**MUTUAL COUPLING DUE TO MONOPOLES FAR APART OR NOT PARALLEL
    250 T=0.
211
212
          SGN=-1.
213
          P11=(0...6)
214
          F12=(U...U)
215
          D21=(U...U)
216
          D22=(0...0)
217
          F11=(U...0)
218
          F12=(0...0)
219 C
          CO TO 15
220
          no 260 IN=1.1P
```

```
221
           PU(1)=YC(LA)+IT/TPL)*CA
222
           EU(2)=YC(LA)+(T/TPL)*CB
223
           HU(3)=2C(LA)+(T/TPL)*CG
224
           CALL GMF(XC(MA)+YC(KA)+ZC(KA)+XC(KB)+YC(KB)+ZC(KB)+RO(1)+
_25
           &RO(2).RO(3).AM.DC(K).CGDS.SGDS.ETA.GAM.EX1.EY1.EZ1.EX2.
226
           8FA5 (E15)
           VRITE (8 .-) IL .EX1.FXS
227 r
228
     12
           TALL REGIOW (RSA . RO . RRT . CR . VMP . - 1 . - 1 . TELL . MPLC . - 1 . MOP . MM . NOP . NOC)
229
           IF (TELL) 60 TO 13
230
           E 11=EX1*CA+EY1*CB+EZ1*CG
231
      13
           CALL REGION(RSR. RO. RRT. CR. VMP.-1.-1. TELL. NPLC.-1. NOP. MM. NOP. NOC)
232
           1F (TELL ) GG TO 14
233
           F12=EX2*LN+FY2*CB+FZ2*CG
234
           CC=3.+5GN
235
           IF (IM.EQ.1 .OR. IM.EQ.IPICC=1.
236
           CC1=CC*SIM(LL-T)
237
           CC2=CC*Slb(T)
230
           P11=P11+L11*CC1
239
           P12=P12+t I1*CC2
240
           P21=P21+E12+CC1
241
           P25=b55+F15+CC5
242
           T=T+DELT
243
      260
           CGM=-SGM
244
           CST=-(6.+1.)*(DELT/TPL)/(3.*SGUT)
245
           0(1:1)=CST*P11
246
           0(1.2)=CST*F12
247
           0(2.1)=CST*P21
248
           c(2.2)=C5T*F22
249 C**MEXT CONSIDER MUTUAL AND SELF COUPLINGS DUE TO REFLECTION
 "50 C**AND DIFFRACTION MECHANISM
251
     14
           T=n.
252
           S6N=-1.
253
           R11=(0...0)
254
           £12=(0...0)
255
           P21=(U. . . U)
256
           F22=(0...6)
257 r
           60 TO 15
258
           00 270 IN=1 . IP
259 C**FIRST CONSIDER COUPLINGS DUF TO REFLECTIONS
260
           FR1=(U. . . 0)
261
           ER2=(0...0)
262
           70 5 15=1.NOP
           RU(1)=XC(LA)+(T/TPL)*CA
263
264
           BO(S)=YC(LA)+(T/TPL)*CP
265
           HO(3)=2C(LA)+(T/TPL)*CG
266 r
           WRITE (8 .- ) 10 . 15
           CALL IMAGE (FSA. KIA. 15. NIMA. VMP. NPLC. CR. NOP. NOC)
267
           CALL IMAGE (RSP. RIH. 15. NIMA. VMP. NPLC. CR. NOP. NOC)
266
           CALL REGION (RIA+KO+RKT+CR+VNP+-1+-1+TELL+NPLC+-1+NOP+MM+NOP+NOC)
269
270
           TF (MM. F. 15)60 TO 51
271
           TF ( . NOT . TELL) GO TO 51
272
           no 33 133 =1.3
273
      32
           PRT1(133)=RRT(133)
274
           CALL REGION (RSA+KRT1+RRT+CR+VNP+=1+=1+TELL+NPLC+=1+NOP+MM+NOP+NOC)
275
           TRITELI 160 TO 51
```

```
(ALL GAF(R)R(1).RIB(2).RTB(3).RIA(1).RIA(2).RIA(3).RO(1).
276
277
           SRO(2) . RU(3) . AM . DC(K) . CGDS . SGDS . FTA . GAM . EX1 . EY1 . EZ1 .
278
           xEY2. EY2. E221
           FR1=ER1+EX2*CA+EY2*CB+EZ2*CG
279
           TALL REGION (RIP, KO, RKT, CR, VNP, -1, -1, TELL, NPLC, -1, NOP, MM, NOP, NOC)
280
           TE (MM. NF. 15) GO TO 5
281
282
           IF ( . NOT . TELL) GO TO 5
285
           110 34 134=1.5
284
           FRT1(134)=RKT(134)
           TALL REGION (RSR, RKT1, RRT, CK, VNP, -1, -1, TELL, NPLC, -1, NOP, MM, NOP, NOC)
285
286
           TELTELLIGO TO 5
287
           CALL G'F(RIP(1) + RIP(2) + RIB(3) + RIA(1) + RIA(2) + RIA(3) + RO(1) +
835
           xRO(2).RU(3).AM.DC(K).CGDS.SGDS.ETA.GAM.EX1.EY1.EZ1.
234
           SEXSOFICE)
           FR2=ER2+EX1*CA+EY1*CB+EZ1*CG
290
          FURMAT(615)
291
     666
292
     5
           CONTINUE
293
           FT2=ER2
294 (**
295
           CC=3.+8G0
296
           TF(IM.10.1 .OF. IN.EQ.IP)CC=1
297
           CC1=CC*SIM(PL-T)
298
           CC2=CC*SIN(T)
299
           P11=R11+ET1*CC1
           112=R12+FT1*CC2
300
301
           221=K21+ET2*CC1
302
           H22=R22+F T2*CC2
303
           T=T+DELT
304
     270
           SGN=-SGN
           T=P.
305
     280
300
           c611=-1.
307
           P11=(U...U)
308
           P12=(0...0)
309
           F21=(0...0)
310
           E22=(0...0)
311 C
           60 TO 17
312
           PU 100 IN=1.IP
313 C*****EXT FIND DIFFRACTED FIELD PARALLEL TO EXPANSION MONOPOLE
314 C*** PUF TO LHO POINTS OF TEST MUNICIPULE
315
    16
           FD1=CMPLX(0...0)
316
           FD2=CMPLX(U... n)
317
           PU(1)=YC(LA)+(T/TPL)*CA
318
           FU(2)=YC(LA)+(T/IPL)*CR
           PU(3)=20(L/)+(T/TPL)*CG
319
320 C
           GU TO 15
321
           DU 6 16=1.MOP
322 C
           WRITE (d.-) 10.75.16
323
           nu 6 Jh=1.4
           K1=U6+1
324
           IF (J6.+0.4)+1=1
325
326
           KZ=NPLC(16,06)
327
           KS=NPLC(I6,K1)
328
           PO 7 J7=1.3
329
           (1(U7)=CK(K2+U7)
330
           CZ(U7)=CK(K3,U7)
```

```
331
     7
           CONTINUE
352 C***AVE ID CONSTDER THE SAME FORE TWICE
333
           CALL COMEDITE. C1.C2.CR. NPLC. NCED .- 1. NOP. NOC)
334
           IF (NCE" . 6T. 0) 60 TO 6
335
           F1S=CMPLX(0...0)
336
           FIH=CMPLX(U... n)
337
           FUS=CMFLX(0...0)
338
           EDH=CMPLX(0...0)
339
           CALL WEDIFF (PSA+C1+C2+PO+RD+T6+=1+AM+WAVM+NCM+VNP+CR+NPLC+
340
           2NOP . NOC . VENS . VPHNS . CONS1 . VB1 . VB2 . IDIF . VBND . VPHND)
           IF (IDIF.LE. 0) GO TO 8
341
342
           TALL GMF(RSA(1) PRSA(2) - RSA(3) - RSP(1) - RSP(2) - PSP(3) - PD(1) -
345
           xkn(2) +RD(3) +AM+DC(K) +CGnS+SGDS+ETA+GAM+EX1+EY1+EZ1+EX2+
344
           8EY2.E721
345
           FIS=EX1*VBNS(1)+EY1*VBNS(2)+FZ1*VBNS(3)
346
           EIH=EX1*VPHMS(1)+EY1*VPHMS(2)+E71*VPHMS(3)
347
           FUS=-(VB1-VB2)*EIS*CONS1*AFAC
348
           FDH=-(VB1+VB2) *EIH*CONS1*AFAC
349
           EU1=EU1+EUS*(VBND(1)*CA+VBND(2)*CB+VBND(3)*CG)+
350
                    EDH*(VPHND(1)*CA+VPHND(2)*CB+VPHND(3)*CG)
351
     8
           FIS=CMPLX(0.,.0)
           FIH=CMPLX(0...0)
352
353
           FUS=CMPLX(0...0)
354
           FUH=CMPL>(0.,.0)
355
           CALL WEDIFF (RSR.C1.C2.RO.RU.J6,-1.AM.WAVM.NCM.VNP.CR.NPLC.NOP.
356
           RNOC . VANS . VPHNS . CONS1 . VB1 . VB2 . InTF . VBND . VPHND)
357
           TF(IDIF.LF.0) GO TO 6
           CALL GNF(RSA(1) . RSA(2) . RSA(3) . RSB(1) . RSP(2) . RSB(3) . RD(1) .
358
359
           RKD(2) + RD(3) + AM + DC(K) + CGDS + SGDS + ETA + GAM + EX1 + EY1 + EZ1 +
360
           REX2, EY2, EZ2)
           EIS=EX2*VBNS(1)+EY2*VBNS(2)+FZ2*VBNS(3)
361
362
           FIH=EX2*VPHMS(1)+EY2*VPHMS(2)+E72*VPHMS(3)
           FUS=-(VB1-VB2)*EIS*CONS1*BFAC
363
364
           FDH=-(VB1+VB2)*EIH*CONS1*BFAC
365
           ED2=ED2+EDS*(VRND(1)*CA+VBND(2)*CB+VBND(3)*CG)
366
                   +EDH*(VPHND(1)*CA+VPHND(2)*CB+VPHND(3)*CG)
367
           CONTINUE
     6
368
    C**
369
     15
           ET1=EU1
370
           FT2=ED2
371 C**
372
           CC=3.+SGN
373
           JF(IN.EU.1 .OR. IN.EG. IP)CC=1
           CCI=CC * STILLET - L)
574
57:
           (C)=(C+3,1(1)
37h
           F11=P11+ET1+CC1
377
           P12=P12+ET1*CC2
375
           P21=P21+ET2+CC1
375
           L55=655+F15*CCS
380
           T=T+DELT
351
     100
           56" = - Sing
382
    17
           CST=-(0.+1.)*(DELT/TPL)/(3.*CGDT)
38, **
364
           D(1+1)=CST*(R11+P11)
31.5
           (1.21=757*(H12+P12)
```

```
366
           F (2+1)=CST*(R21+P21)
30 7
           F(2+2)=CST*(R22+P22)
           (1J=F1*FJ*P(1S.JS)+F1*FJ*G(1S.JS)
 seid
     166
 300
            1+ (J.GT.NCM) GO TO 190
 390
           C(I+J)=C(I+J)+CIJ
391
           IF (I.Mt.u) C(J,T)=C(J,I)+CIJ
 392
           00 TO 200
395
      190
           do=d-dr P
 504
           C(1,Jb)=C(1,JG)-CIJ
39
      200
           CONTINUE
 396 C**LOAD IMPERANCE INSERTED HERE IN C MATRIX
      262 IF (NLO.LE.0) GO TO 300
397
 39€
           10 282 1=1.11CM
399
           JUA=JA(I)
400
           ALLUUA
401
          IIS=IS(I)
402
           111=11(1)
403
           JEITIZ.FG. TR(J1)) J1=J1+NRS
404
          IF ( T. LE . HPGP) GO TO 272
405
           JUP=JH(I)
400
           Je=JUB
407
           1F(112.EG.18(J2))J2=J2+NRS
400
           C(I+I)=C(X+I)+ZLD(J1)+ZLD(J2)
409
           JUJ=JUA
410
           DU 265 K=1.2
           I DJ=ND (JJJJ)
411
 414
           DU 266 JU=1 . NOJ
           (LU, LUU) OM=L
413
414
           IF (U.LO.1)60 TO 266
 415
           1+ (12(J).NF.112)60 TO 266
-410
           F1=1.
411
           TF (K.t.O. .. ) 60 TO 264
410
           IF (11(U) . HE . 111) FI==1.
419
           C(I+J)=C(I+J)+FI*ZLD(J1)
420
           CU TO 266
421
      264
          IF'13(J).MF.13(1))FI=-1.
           C(T+J)=C(T+J)+FI*ZLD(J2)
46
 465
      236
           CONTINUE
424
           JJ.1=JJ0
      268
 4.20
           60 70 242
426
      272 IF (IB(U1).LE.MPGP)J1=J1+NRS
           C(I,I)=C(I,I)+2.*ZLD(J1)
42.7
420
           MUJUERUL JUA)
629
           10 278 JUEZ , MUJ
130
           J=MD(JJA.JJ)
           IF (J.Ed.1)60 TO 278
451
 432
           TF (12(d).NF.112)60 TO 278
4.33
           F 1=1.
431
           TH ().1(J).(H.111)FI=-1.
450
           c(1.d)=c(1.d)+2.*F1*2Ln(J1)
450
      270 CULTLIVE
437
      232 CONTINUE
450
      370
           PETURN
435
           CHAIN
```

## APPENDIX 11 SUBROUTINE CIFFLD

This subroutine is listed in Figure A.11 and is essentially the same as subroutine IFFELD of reference 2, except for the CALL CZFF statement, where CZFF calculates the far zone field of a monopole above the satellite structures (see Appendix A.11).

Let  $(r,\theta,\phi)$  denote the spherical coordinates of the distant observer, and let E (I), I (I) denote the electric field intensities of dipole mode I with unit current. Then

$$\begin{aligned} & \text{EPP(I)} &= r \ e^{jkr} \ E_{\theta}(I) \\ & \text{ETT(I)} &= r \ r^{jkr} \ E_{\theta}^{\phi}(I) \end{aligned}$$

Summing the fields due to all modes I yield

$$EPH = \sum_{i=1}^{N} CJ(i)EPP(i)$$

$$ETH = \sum_{i=1}^{N} CJ(I)ETT(I)$$

where CJ(I) denote the terminal current of mode I

CALL statement

CALL CIFFLD (INS,MD,N,ND,NRS,CDK,CJ,DC,EPH,ETH,G,CPP,GTT,PH,SDK,TH,XC,YC,ZC,WAVM,AM,NPGP,NCM,VNP,NPLC,CR,NOP,NOC,IDSEG)

All symbols have been defined in previous subroutines.

```
1 C**SURPOUTINE SIMILAR TO IFFLE
          SURROUTINE CIFFLD (INS. MO. N. N. P. S. CUK, CJ.DC.
 d
          SEPH, ETH. 6, GPP. GTT. PH. SOK, TE. XC, YC. ZC . WAVM, AM, NPGP.
 3
          ANCW AND OTHER COCK ONOD ONOC TOSE ()
 4
          CUMMON/CUMS/IN.18.JA.JA.11.12.13
 )
          DIMENSION VIP(NOP.3).MPLC(NOP.4).CK(NOC.3).I(SEG(65)
 1
          COMPLEXEPHOFTHOCULOFTIOETZOEPLOFFZ
          DITENSION FO(65.4) . 110 (65)
 9
          CUMPLE YOU(1) . FPP (32) . ETT (32)
10
          DIMENSIONCHK (1) . SUK (1) . DC (1) . XL (1) . YC (1) . ZC (1)
11
          DIMENSION [1(70) •12(70) •13(70) •11(65) •18(65) •JA(70) •JB(70)
          PATA CUT/(U., -0.540888F-2)/
12
13
          THR=.0174535*TH
14
          CTH=CUS(IHF)
15
          STH=SIM(IHR)
          PHF=.0174533*PH
16
17
          CPH=CUS(PHH)
          SPH=SIMITHE
10
19
          10 130 I=1.NCM
20
          FIT(1) = (0.,.0)
21
    130
          FPP(I)=(U,,.U)
23
          PU 140 K=1.65
23
          KA=IA(K)
24
          48=18(K)
          CALL CZEF (XC(KA)+YC(KA)+ZC(KA)+XC(KR)+YC(KB)+ZC(KP)+BC(K)+KA+KB+
25
          YWAYM+AM+C(PK(K)+SOK(K)+CTH+STH+CPH+SPH+FT1+ET2+EF1+EP2+NF6P+
20
27
          RIVEM . VIDP . NELC . CK . MOP . NOC . 105FG (K) . MO)
          FURMAT (4X . AFTER CZEL !)
28
29
          HUK=MO(K)
30
          10 140 II=1.NDK
31
          1=10(K.II)
32
          F1=1.
          TE (KB. E0.12(1))60 TO 136
33
34
          IF (KB.E0.I1(I))F1=-1.
35
          + PP(I)=FP+(I)+F1*EF1
          ELL(T)=ELL(T)+ET*ELT
36.
57
          50 TO 141
          TF (KA.EG. 13(1)) F1 == 1.
30
    130
39
          + PP([]=EPP([]+F1*EP2
41)
          FTT([)=ETT(])+F1*ET2
41
    140
          TUNT IN !!
42
          FPH=(U. . . . !!)
          FTH= (0...0)
45
         10 260 I=1.0CM
44
    200
45
          FIH=ETH+LJ(1)*FIT(T)
46
    260
          FPH=EPH+CJ(1)*EPP(I)
          APPECAUS (EPH)
47
48
          ATT=CABS(ETH)
          CHP=APP*APP/(30.*G)
49
511
          CIT=AII*ATT/(30.*6)
51
          RETURN
          FINE
52
```

Figure All. Subroutine CIFFLD.

# APPENDIX 12 SUBROUTINE CZFF

CZFF is listed in Figure A.12.

Submatrix CZFF calculates the far zone field of a monopole above a satellite body modeled by flat plates. CZFF includes contributions from incident, reflected, singly diffracted and doubly diffracted fields. All phase terms of these fields are referred to the origin of the coordinate system before summation.

Between statement of 26 and 30 the direct incident field region is defined and the incident field computed by calling subroutine GFF (reference 3). The fields due to reflected rays are computed in loop Do 5. Do 6 defines diffraction region and computer singly diffracted fields. Doubly diffracted fields are evaluated between statements 80 and 40. Finally the total field arrives at the observation point due to each end of the monopole is the sum of the above field components. Summation is performed between statement 40 and RETURN.

CALL statement:

CALL CZFF (XC(KA),YC(KA),ZC(KA),XC(KB),YC(KB),ZC(KB),DC(K),KA,KB, WAVM,AM,CDK(K),SDK(K),CTH,STH,CPH,SPH,ET1,ET2,EP1,EP2,NPGP, NCM,VNP,NPLC,CR,NOP,NOC,IDSEG(K),MD)

ET1,EP1 are  $\theta$  and  $\varphi$  components of the far field due to endpoint 1, ET2, EP2 and those due to endpoint 2. Other symbols have been different previously.

```
1
          OPTIONS 32K
          SUPROUTINE CZEF(XC1.YC1.ZC1.YC2,YC2,ZC2.DCK.KA.KB.WAYM,AM.
 2
 5
          ºCPKK.SOKK.CTH.STH.CPH.SPH.FTI.ETZ.EPJ.FPZ.NPGP.NCM.VMP.
          *NPLC . CR . NOP . MOC . InSEGK . ML )
 5 C** THIS SUBROUTINE CALCULATES THE FAR ZUME FIELD OF A MUMOPPULE
 6 C** WEAR OR ON A CONDUCTING HONY MODELLE: BY FLAT PLATES
 7 C** SUDPOUTINES CALLED: REGION. THAGE . SEF. COMEU. REDIFF. GNF. CROSSE
 & C** OUTPUT: LT1 . LT2 . EP1 . LP2
 7 C++L.L. UDAH . MAY 76.
         LUGICAL TELL
10
         COMPLEX tillereepintpengameria, cous. sons. Els. Elm. tos. Elm
11
         COMPLEY EITI . FTP1 . FRT1 . FRP1 . FOT1 . EUP1 . EIT2 . FTP2 . E . P2
12
13
         COMPLEX ERT2.ENT2.FOP2.ENDT1.EUDT2.FD0P1.ED0P2
14;
          COMPLEX VEL. VB2. COMSI. EXI. EY1. EZ1. EX2. EX2. EZ2
15
         DIFENSION AD (65.4)
         DIMENSION VI(3). RO2(3).DN(3).EDN(3).VRDS2(3).VPENS2(3)
1+.
          I INEMSION TEP (MOP. .) . MPLC (MOP. +) . CK (MOC. 3) . MAN (3) . VAL (3)
17
         "IMENSION RET(3).RO(3).C1(3).C2(3).PD(3).RET)(3).PDU(3).6(3)
11
         1 IMENSIONCS(3).C4(3).RSA(3).PSU(3).FIA(3).EIR(3)
19
20
          OIMENSION VPHNS(3). VPHND(3). VBES(3). VEND(3). VPHND2(3)
21
          :1"ENSTONVBNU2(5).VIHN(5).VTH(3).EUM2(3).V/(3(3).V5(3).VPH.(3)
22
          DATA TP/6.2831355/.PI/3.14159265/
23
          TPI = TP/LIAVE
24
         FIA=(376.727.0.)
25
         GAM=CMPLX(u. . TPL)
26
         CGPS=CMPLX(CDKK.U.)
27
          SUFS=CFPLX(1...SOKK)
26
         RU(1)=STH*CPH
23
         PO(2)=STH*SPH
30
         90(3)=CTF
31
         13A(1)=XC1
32
          650(2)=YL1
         (SA(5)=201
53
34
         "SH(1)=XCZ
30
          754(2)=YL !
36
          05P(3)=ZC2
57
          AFAC=1.11
38
         PFAC=1.0
37 C++ GROUPD PLANE EMMPOINT IS LIFTED UP FOR REFLECTION AND DIFFENCTION
40 C**TEST. THE MUMOPOLE SEGMENT IS ABOVE PLATE LIBEGE
         TE (KA.GT. MPGP .AND. KP.GT. MPGP)GO TO 26
41
          IF (KB.LL. MPGP) GO 10 82
40
45
         (SA(1)=XC1+1.F-06*VNP(IDREGK.1)
44
          254(2)=YC1+1.F-06*VNP(IDSEGK.2)
         "S4(3)=201+1.F-06*VMP(IDSEGF.3)
45
46
         FAC=U.5
47
         10 TU 26.
         1514(1)=XC2+1.F-U6*VHP(IPSEGK,1)
4 2
    20
4.4
         DSQ(2)=YCZ+J.F-OE*VAIP(IDSEGK.2)
50
          75P(3)=ZCZ+1.1-06*VVP(IDS(6K.3)
51
          HEACTU.5
52 C * PERIOE DIRECT FIFLD REGION AND COMPUTE DIRECT INCLUENT FIELD
53
   24
         F111=(0. . . 0)
          · 101=(0. . . . 0)
24
55
          EI_{\perp S}=(u^{**}0)
```

Figure A12. Subroutine CZFF.

```
56
           F1P2=(0...0)
 57
           FRT1=(0. . . . . )
 50
           FRP1=(0...0)
 54
           FRT2=(0. . . . . )
 60
           [KP2=(0. . . 0)
 61
           FUT1=(0. . . . )
 62
           EDP1=(U. .. 0)
           FLT2=(0. . . U)
 65
           F(102=(0...0)
 64
 65
           VP4N(1) =-SPH
           MEHAI(S)=CEH
 tit.
 67
           VPHN(3)=U.
 68
           CALL CROSSE (VPHN. RO. VTHN. VTH)
 69
           : DOTI=(0. . . 0)
 70
           FUNT2=(0...6)
 11
           FUNP1=(U.,.U)
 72
           FUCP2=(0.,.0)
 75
           CALL GFF(RSA(1).RSA(2).RSA(3).RSA(1).RSA(2).RSA(3).DCK.CGUS.
 74
           *SGDS+CTH+STH+CPH+SPH+GAM+ETA+LT1+LT2+LP1+EP21
 7:
           CALL REGION (RSA+KO+RKT+CR+VMP+-1+-1+TELL+MPLC+1+MOF+MM+NOP+NOC)
 76
           IF (TELL) GO TO 28
 77
           FITT=E F1 * AFAC
 11
           FIPI=EPI*AFAC
 79
     29
           CALL REGION (RSR. RO. RRT. CR. VNP. - ] . - 1, TELL, HPLC. 1. NCP. NM. NCP. NGC)
 08
           IFITELLIGO TO 30
 81
           FIT2=ET2+BFAC
 82
           FIP2=EP2*BFAC
 83 C** DEFINE REFLECTION REGION AND FIND REFLECTED FIELD
 84
     30
           DU 5 15=1 . NOP
 68
           CALL IMAGE (HSA+KIA+15+NIMA+VNP+NPLC+CH+NOP+NOC)
80
           CALL IMAGE (KSB. KIB. IS. MIMA. VMP. NPLC. CR. NOP. MOC)
 87
           CALL GFF(RIS(1) *RIP(2) *RIB(3) *RIA(1) *RIA(2) *RIA(3) *OCK *CGOS*
           *SGUS.CTH.STH.CPH.SPH.GAM.ETA.LT1.LT2.LP1.LP2)
 88
           CALL REGION (RIA.KO.RKT.CR.VNP.-1.-1.TELL, NPLC.1.NOP.MM.NCP.NOC)
 89
           1F (MM. MF. 15)60 TO 32
 90
           TE ( . NOT . TELL) GO TO 32
 91
 92
           110 31 I=1.3
 93
     31
           ERT1(I)=KRT(I)
 94
           CALL REGION (RSA+RRT1+RRT+CK+VHP++1++1+TELL+MPLC++1+MOP+MM+MOP+NOC)
 95
           TF (TELL) GO TO 32
 94
           CALL REGION (RRT1 . KO . RRT . CK . VNP . - 1 . - 1 . IELL . MPL C . 1 . MOP . MM . COP . NUC)
 97
           TF (TELL) 60 TO 32
 96
           FRT1=ET1*AFAC
 99
           ERP1=EP1*AF/C
     32
           CALL REGION (RIP+KO+RKT+CP+VMP+-1+-1+TELL+HPLC+1+NOF+MM+NOF+NOC)
100
101
           TECMM . ME . 15 160 TO &
102
           JF ( . NOT . TELL ) GO TO 5
103
           00 33 I=1.3
104
     33
           FRT1([)=KR1(])
105
           CALL REGION (RSR. KKT1. RRT. CR. VMP. - 1. - 1. TELL. NPLC. - 1. NOP. NOP. NOP. NOC.)
106
           JE (TELL) GO TO 5
107
           CALL REGIOI (RRT1 . KO . RKT . CK . VMP . - 1 . - 1 . TEI L . MPLC . 1 . LOP . MM . NCP . NOC)
           TELLEGO TO 5
100
109
           EHTZ=E12*BFAC
           FKFZ=EP2+BFAC
110
```

```
111 5
          COMTINUE
12 C** DEFINE DIFFRACTION REGION AND FINE DIFFRACTED FIFLD
113
          nu à le=1. NCP
114
          AUPAZE =1 .
115
          PU 6 J6=1.4
116
          ×1=J6+1
117
          TF (J6. + Q. 4) K1=1
116
          KZ=NPLC(16,J6)
          KS=NPLC(16.K1)
114
120
          10 7 17=1.3
121
          C1(J7)=Ch(K2,J7)
          (2(U7)=C1 (K3.U7)
122
123 C
             *AVOID CONSIDER THE SAME FOOF TWICE *
124
          CALL COMED(16, C1, C2, CR, NPLC, NCLD, -1, NUF, NOC)
125
          IF (NCED. 61.0) 60 10 6
          CALL WEDIFF (RSA.C1.C2.RO.RU.T5.1.AM. W/VM.NCM.VNP.CK.DPLC.
126
          127
128
          TE (IDIF.LE. B) GO IL 3
129
          CALL GHE (RSA(1) . RSA(2) . RSA(3) . RSE(1) . ESE(2) . PSR(3) . PD(1) . ED(2) .
          *KO(5). AM. (CK. CGDS, SGDS. FTA. GAM, EX1. FY1. EZ1. EX2. LYK. EZZ)
130
131
          F1S=EX1*VHNS(1)+EY1*VBNS(2)+F21*VENS(3)
132
          FIH=EX1*VPHIS(1)+EY1*VPHIS(2)+F71*VFHIS(3)
133
          FUS=-(VB1-VB2)*EIS*CONS1*AFAC*AGEAZF
134
          FUH=-(VB1+VH2)*EIH*CONS1*AFAC*AGFAZE
135
          FUT1=EPT1+FUS*(VBMP(1)*VTHM(1)+VHMD(2)*VTHM(2)+VPMD(5)*
136
          *VTHM(3))+EMH*(VFHMD(1)*VTHM/1)+VPHMM(2)*VTFM(2)+VPHMM(3)*
137
          SUTHIN(3))
          FUF1=EPP1+EPS*(VEMO(1)*VPHP(1)+VPHD(2)**PHM(2)+VPDU(3)*
150
          #VPHM(3))+FINH*(VPHMD(1)*VPHM(1)+VPHM(2)*VPHM(2)+VPHM(3)*
139
140
141
          CALL WEDIFF (PSR.C1.C2.R0.RH.T6.1.AM.VAVE.NCM.VNP.CK.NPLC.
142
          venop.doc.vens.vehns.coms1.ve1.ves.inif.vano.vehno)
143
          IF ( ID IF . LE . C) 60 10 6
144
          CALL GNF (RSA(1)+KSA(2)+RSA(3)+RSP(1)+RSP(2)+PSP(3)+PP(1)+
145
          THE (2) PU(3) AMODEKOGOS, SEESOETA, GAMOEXI, EYI, EZI, EXZOEYZ,
146
          St721
147
          FIS=EX2*VENS(1)+EY2*VENS(2)+FZZ*VENS(3)
140
          F [H=EX2*VPHNS(1)+EY2*VPHMS(2)+E72*VFHMS(3)
149
          FUS=-(VB1-VBZ)*EIS*CUNS1*BFAC*AGRAZE
          FUH= - (VB1+VHZ) *EIH *COMS1 *EFAC * AGE AZF
150
          FUT2=EUT2+EUS*(VENUE(1)+VTFN(1)+VENU(2)*VTHH(2)+VEUD(3)*
151
152
          2VTHN(3))+EDH*(VPHAD(1)*VTHN(1)+VPHAM(2)*VTHH(2)+VPHAG(3)*
153
          2VTHN(3))
          FDP2=LDP2+EDS*(VBMC(1)*VPHM(1)+VFMD(2)*VPHM(2)+VFML(3)*
154
          yyPHN(3))+EDH*(VPHND(1)*vPHN(1)+vPHnD(2)*yPHn(2)+yPHLD(3)*
155
156
          (( · ) LIHAY?
          CONTINUE
157
    6
154 (**
159 C** CUMPUTE DOUBLE DIFFRACTED FIELD
160 ***----
    80
161
         TU 40 140=10SFGK . ITSEGK
          10 42 042=1.4
162
165
          K1=J42+1
164
          TF ( J42. F 0. 4 ) K1=1
165
          12=NPLC(14(+042)
```

Figure A12 (Cont'd).

```
166
           K3=NPLC(140.K1)
67
           nu 44 J44=1.3
168
           (1(J44)=CR(K2,J44)
     44
169
           (2(J44)=C+(K5,144)
170
           CALL COMEDITAG. CI.CZ.CF. MPLC. MCFP. - 1. NO. , NOC)
171
           1F (DCE0.61.0)60 TC 42
172
           00 47 146=1.3
175
     47
           VN (146)=VIP(140.146)
174
           TALL COMEDITAG. C1.C2.CR. MPLC. NCFC. NOP. NOP. NOC.
175 C** SET UP 210 FIGE WHERE DOURLE DIFFRACTION MAY TAKE FLICE
111
           TF (NCLU-1)42,42,48
177
     44
           10 52 Joz=1.4
           +1=J52+1
170
179
           IF (J52.FC.4) K1=1.
180
           KZD=MPLC(ACED.J52)
181
           K3D=MPLC(MCED.K1)
182
           10 54 354=1.3
183
           13(J54)=CK(F2D,J54)
184
           C4 (U54) = LR (F30+U54)
185
           MM (J54)=VNP (MCFU+J54)
186
           TF ( (K2D. EG. K2) . AND . (K3D. FQ. K3) ) GO TO 52
187
           IF ( (K20.EQ.K3) . AND. (K30.F(.K2)) GO TO 5:
188
           F=SUPT((C4(1)=C3(1))**2+(C4(2)=C3(2))**2+(C4(3)=C3(3))**2)
189
           10 55 155=1.3
190
     55
           + UN2(155)=(C4(155)-C3(155))/F
191 C** DETERMINE DIFECTION OF GRAZING PAY
 92
           COSBS=0.
193
           TU 56 150=1.3
194
           CUSB2=COSB2+EDM2(156)*RO(156)
195
     56
           CUNITIBLE
196
           CALL CROSSP(EDNZ. VN. VN3. V3)
197
           TF (COSP2.GE.0.099999)GO TO 52
           SIN52=SORT(1.-CUSH2**2)
190
199
           no 58 158=1.3
2011
     50
           ((154)=CUSH2*FON2(156)+SINE2*VN3(158)
201 C** FIRST DIFFHACTION
202 C** FIRST FIND FIRST AND SECOND DIFFRACTION POINTS
           CALL DIFFTE (PSA.CI.CZ. VNN.G. VI.SP.ANI.RD. IOX.
203
204
           . VPHUS . VPHUL . VRNS . VBND . PHS . PHU . RN . EPT.)
205
           IF ( IDX . EG . - 1 ) GO TO 61
           CALL DIFFTE (RP.CS.C4.VM.RU.VT.S.ARIZ.RUZ.IDX.
200
207
           *VPHMS . VF HAD . VPMS . VBMD . PHS . PHD . EA . EDM )
           1F(10x.Eb.-1) GU TO 81
206
           CALL WEDIFF (RSA.C).C2.RD2.KD.L40.-1.AM.MAVM.NCM.VNP.CR.NPLC.
209
210
           *NOP . NOC . VEHS . VPHMS . COMS1 . VR1 . V82 . IDIF . VBMD . VPHMD)
211
           IF (IDIF.LE. 0) GO TO BY
212
           CALL GMF (RSA(1)+KSA(2)+RSA(3)+RSA(1)+KSA(2)+RSA(5)+RA(1)+
213
           %KP(2)+RF(3)+AM+FCK+CGPS+SGPS+ETA+GAM+EX1+EX1+EX1+EX2+EX2+EX2+EZ2}
214
           FIS=EX1+VHMS(1)+t Y1*VBMS(2)+FZ1*VPMS(3)
           EIH=EX1*VPHIS(1)+EY1*VFHMS(2)+EZ1*VPHMS(3)
215
           FUS=-(VPI-VP2)*EIS*CUNS1*AFAC
210
217
           FUH=-(VH1+VH2)*EIH*CONS1*AFAC
           CALL WEPIFF (RD.C3.C4.RC.PDZ.NCED.1.AM.WAVM.NCM.VMP.CR.NPLC.
211
           *NOP.NOC.VERS2.VPHMS2.COMS1.VB1.VB2.ILIF.VBMD2.VPHMD2)
219
2211
           THI TOTE . LE . E 1 GC TO BI
```

```
221 C** CHANGE TO COOKDINATE OF SHIP ELLE
:55
           1 A 1 = U .
223
           / A2=0 .
224
           A45=U.
220
           A44=0.
226
           10 70 1=1.3
           AA1=AA1+VEPER(I)*VERS(I)
227
221;
           AAZ=AAZ+VFF ME2(I)*VBNS(I)
229
           AA3=AA3+VRMD2(I)*VPHMS(I)
250
     7"
           *A4=AA4+VPH*(2(1)*VPHNS(1)
231 C** THE LUENT FIELD ON LUCE &
232
           +10=(EDS*AN1+EDH*AN2)*0.5
           F14=(EDS*AA3+FDH*AA4)*0.5
235
234
           rumS1=CumS)+((SP+5)/(S*SP))*rExP((MPL*(9,,TFL*(5F-(SP*S)/(SP+S))*
234
           2214(VUI)**5))
236
           FUS=-(VB1-VB2)*EIS*CONS1
           FUH=- (VB1+VH2)*t 1H*CUES1
237
230
           FDOT1=EOHT1+EDS*(VENU2(1)*VTHN(1)+VONC2(2)*VTHN(2)+VENU2(3)*
239
           & A.LH(P(Q))+E(1H*(ALH(US(7)*A.LH(T)+ALH(E(S(5)*A.LH(C)+ALH(E(Q)*
240
           SUTHV(3))
241
           FUPP1=FDUP1+EDS*(VPNU2(1)*VPHN(1)+VFFU2(2)*VPHN(2)+VHNU2(3)*
242
           * VPHN(*))+FEH*(VPHNO2(3)*VFHN(3)+VPHNC2(2)*VDHN(3)+VPHND2(3)*
243
           x vPHe (3)1
244
           CALL GIFFTF (RSB+C1+C2+VMM+b+VI+SF+AFI+R++IDX+
     31
245
           XVPHOS. VPHOO. VPPS. VBAD. PHS. PHC. RE. EDA)
246
           IF (1UX.EN.-1)60 TO 52
247
           CALL DIFFTH (RE.C3.C4.VN.RO.VT.S./MIZ.FUZ.IDX.
240
           * VPHINS . VI HI U . VRMS . VBID . PHS . PHD . PR . EDIN)
249
           IF (IDX . F G . - 1) GO TO 52
25.
           CALL WEDIFFIRSA-CI.CC. RD2. KU. 140.-1. AF. D AVM. MCM. VEP. CR. NILC.
251
           2MOP.HOC.VFES.VPHNS.COMS1.VP1.VB2.IPJF.VBHD.VPHHH)
           1F(101F.LE. 0)60 TO 58
252
           CALL GMF (ESA(1) . RSA(2) . RSA(3) . RSP(1) . PSP(2) . RSB(3) . RB(1) .
233
254
           5K7(2) •R1(3) • AM•DCK • CCDS • SGFS • ET# • GAM • E ¥1 • E¥1 • E Z1 • E ¥2 • E ¥2 • E Z2)
255
           F19=Ex2*VRNS(1)+EY2*VRNS(2)+FZ2*VPNS(3)
254
           EIH=EX2*VPH::S(1)+EY2*VPHMS(2)+EZ2*VPFMS(3)
257
           FUS=-(VB1-Vb2)*E1S*COMS1*BFAC
250
           FOR==(VB1+Vb2)*EIH*CONS1*EFAC
259
           CALL WEDIFF(PD.C3.C4.RO.PDZ.NCED.1.AM.WAVM.PCM.VEP.CF.NPLC.
2611
           *HOP+FOC+VEHS2+VPHMS2+CONS1+VB1+VB2+JHIF+VBHHD2+VFHMD2+
           THITOIF.LE.0160 TO 52
261
262 C** CHANGE TO COCKDINATE OF PHIN ELICE
263
           AAJ=0.
264
           AA2=0.
265
           ^A3=0.
261.
           1.44=0.
261
           no 84 T=1.3
           AAJ=AAL+VRNO2(I)*VENS(I)
268
269
           AAP=AAZ+VPHMU2(I)*VBMS(I)
270
           AA3=AA3+VPROP(T1*VPHPS(I)
271
    64
           AA4=AA4+VPHMU2(I)*VPHMS(T)
272 1**
         THE I PENT FIELD ON LUGE ?
: 75
           : Ta=(FU2*VV]+EUH+LV5)*0'E
274
           1 IH=(FUS*FVS+EDH*VVA)*0.5
275
           cofS1=ComS1*((SP+S)/(S*SP))*rEXP(CMPLX(n.,TPL+(SP=(SF*S)/(SP+S))*
```

```
276
          *SIN(ANI)**?))
277
          FUS=-(VB1-VB2)*EIS*CONS1
278
          FUH=-(VR1+VE2)*EIH*CONS1
279
          FDOTS=EDDTS+EDS*(VENUS(1)*VTHN(1)+VFNUS(2)*VTHN(2)+VBNUS(3)*
280
          $VTHN(3))+EPH*(VPHND2(1)*VTHN(1)+VPHNC2(2)*VTHN(2)+VPHNU2(3)*
281
          PVTHN((1))
286
          FUPP2=EDUF2+EPS*(VFND2(1)*VPHN(1)+VFND2(2)*VPHN(2)+VHDD2(3)*
265
          * VPHII(5))+FIH*(VPHINDS(1)+VPHIN(1)+VPHINLS(2)*VPHIL(5)+VPHINLS(3)*
284
          9 VPH(: (3))
285
    52
          CUNITIMUL
    42
28€
          TUI TIMUE
    40
267
          CULTINIE
266 C**IF SUMMING ALL FIFLDS THE COMMON FACTOR EXP(-JKS)/S IS OMITTED
289 C*+HOWEVER CARE IS TAKEN TO INSURF COMMON PHASE REFFRENCE FOR EXP(-UKS)
290 C**MAMFLY. THE UNIGIN OF COORDINATE SYSTEM
291
          FT1=E111+EFT1+FUT1+EUUT1
242
          FT2=E1T2+ERT2+EUT2+EU0T2
293
          FP1=EIP1+ERP1+EOP1+EUDP1
94
          FP2=E1P2+ERP2+F0P2+ED0P2
295
          PETURN
296
          FIJF.
```

Figure A12 (Cont'd).

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